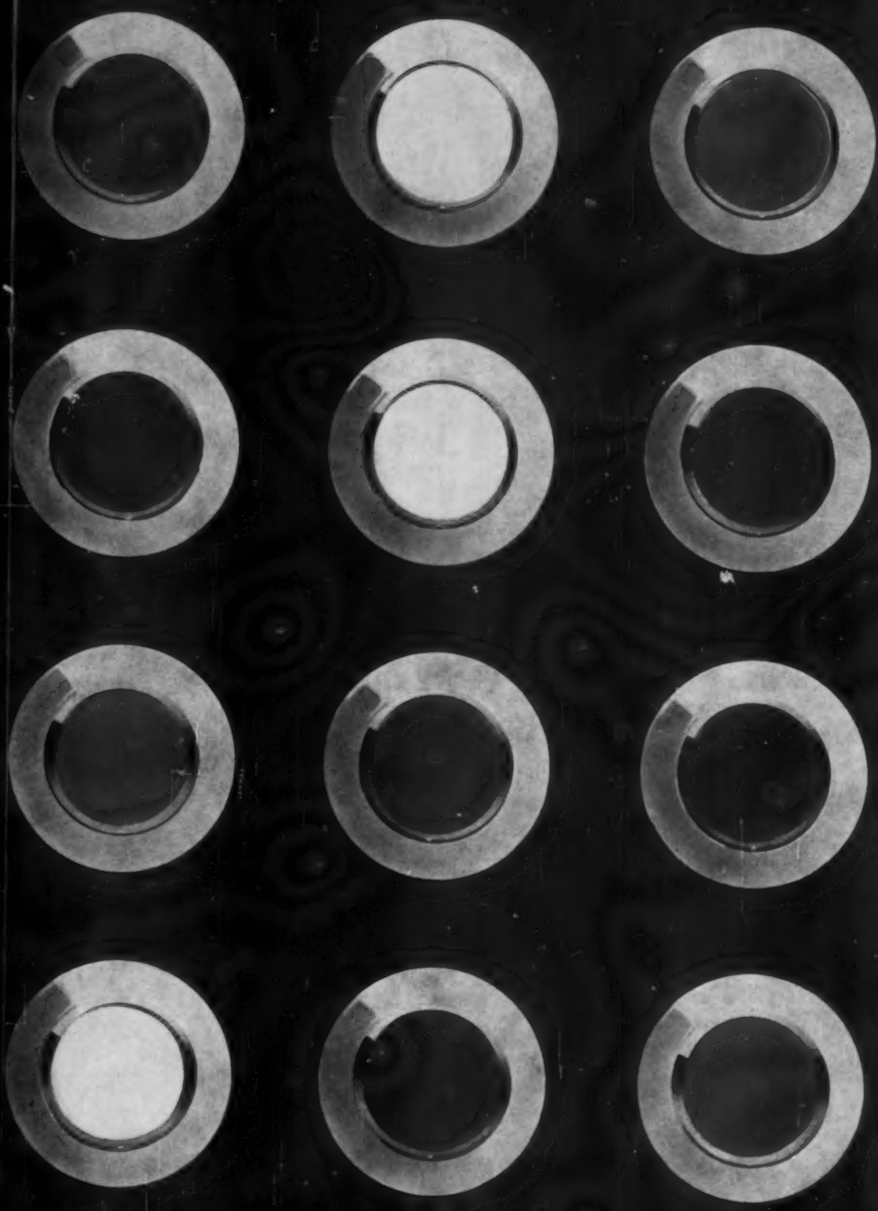
metal progress



December 1959

Complete modern facilities...
exacting quality control...
fast, flexible service...

for mill products and custom conversion of

REACTIVE AND REFRACTORY METALS

MATERIALS	FORM	SIZE	CONDITION
Molybdenum	Rod	½" diameter and smaller	Straightened and cut, centerless ground, annealed or heat treated
Tungsten	Wire	⅜" diameter down to .005" diameter, or finer on request	Straightened and cut, coil and spooled (level or layer wound)
Titanium	Shaped and Flattened Wire		Hexagonal, rectangular and special shaped
Zirconium	Strip	Up to 10" wide and down to .005" thick	Annealed or temper rolled
Tantalum	Foil	Up to 3" wide and down to .0005" thick	Annealed or temper rolled
Columbium			
Tailor-made Alloys			

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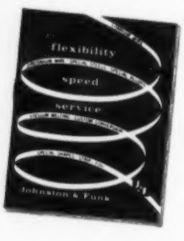

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METALLURGICAL CORPORATION

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Metal Progress

December 1959 . . . Volume 76, No. 6

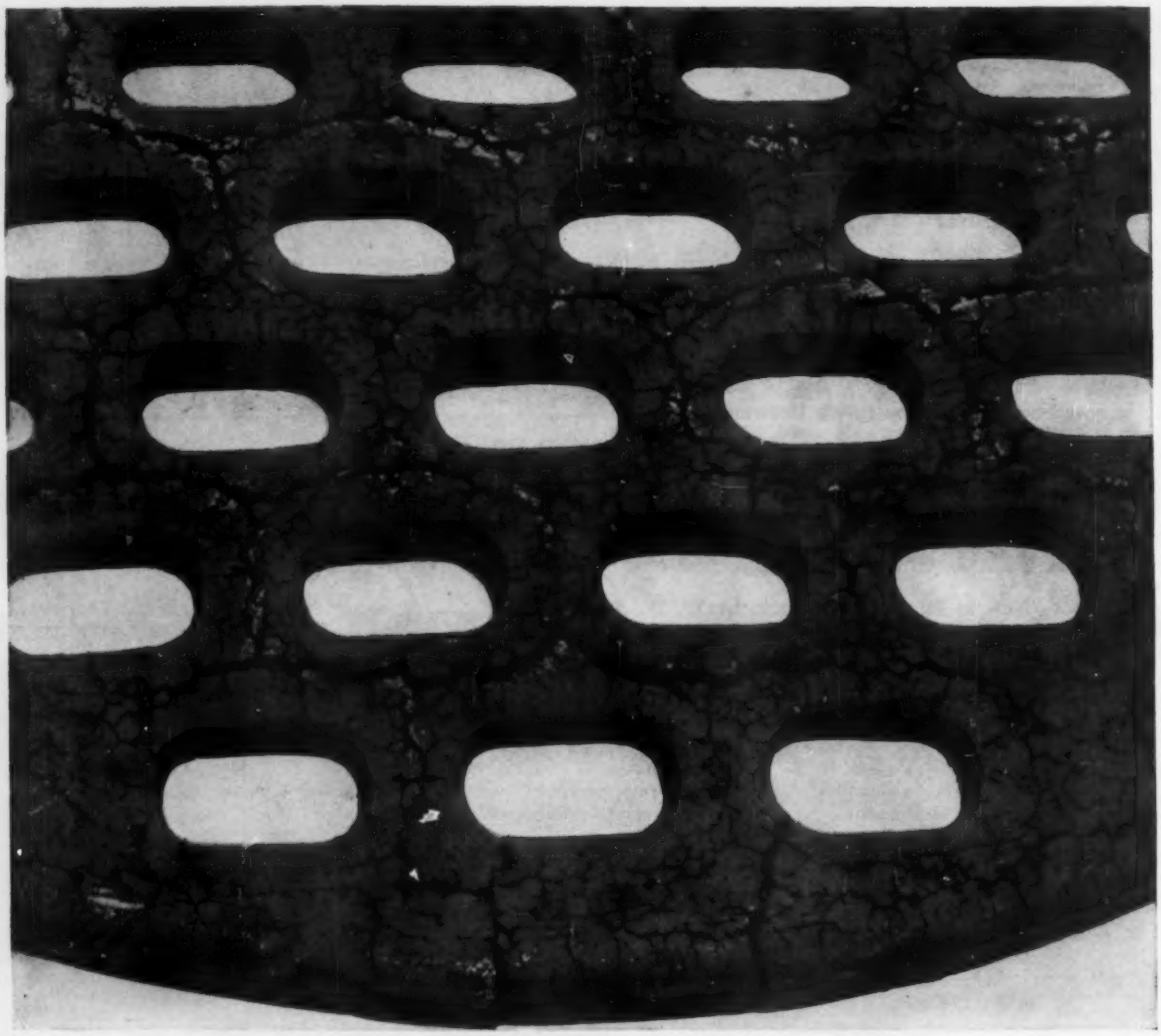
Cover: The push button design, by Robert L. Gault, a prizewinner in the annual *Metal Progress* cover competition at Cleveland Institute of Art, symbolizes the increasing automation of the metal industry—even in literature searching, as described last month on p. 123.

Progress in High-Temperature Materials

Engineering Articles

Table of Contents Continued on Page 3; Volume Index on Page 223

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

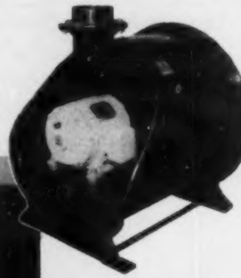


Metal Progress

Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices Metals Park, Novelty, Ohio. Entered as second class matter at the Post Office in Mt. Morris, Ill. Vol. 76, No. 6, December 1959.

RELIABLE SPENCER BLOWERS

FILL MANY NEEDS AT NEW KAISER ALUMINUM PLANT



Ravenswood Works, Kaiser Aluminum & Chemical Corporation, Ravenswood, West Virginia

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- Soaking Pits

SPENCER BLOWERS WERE SELECTED BECAUSE OF THEIR *PROVEN* ADVANTAGES:

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- Power savings (air delivered only in proportion to requirements).
- No special foundations, grouting or bolting down necessary.

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For complete specifications on Spencer Blowers—from 1/3 to 1,000 H.P., volumes up to 20,000 C.F.M., pressures from 4 oz. to 10 lbs.—request Catalog 126B.

SPENCER

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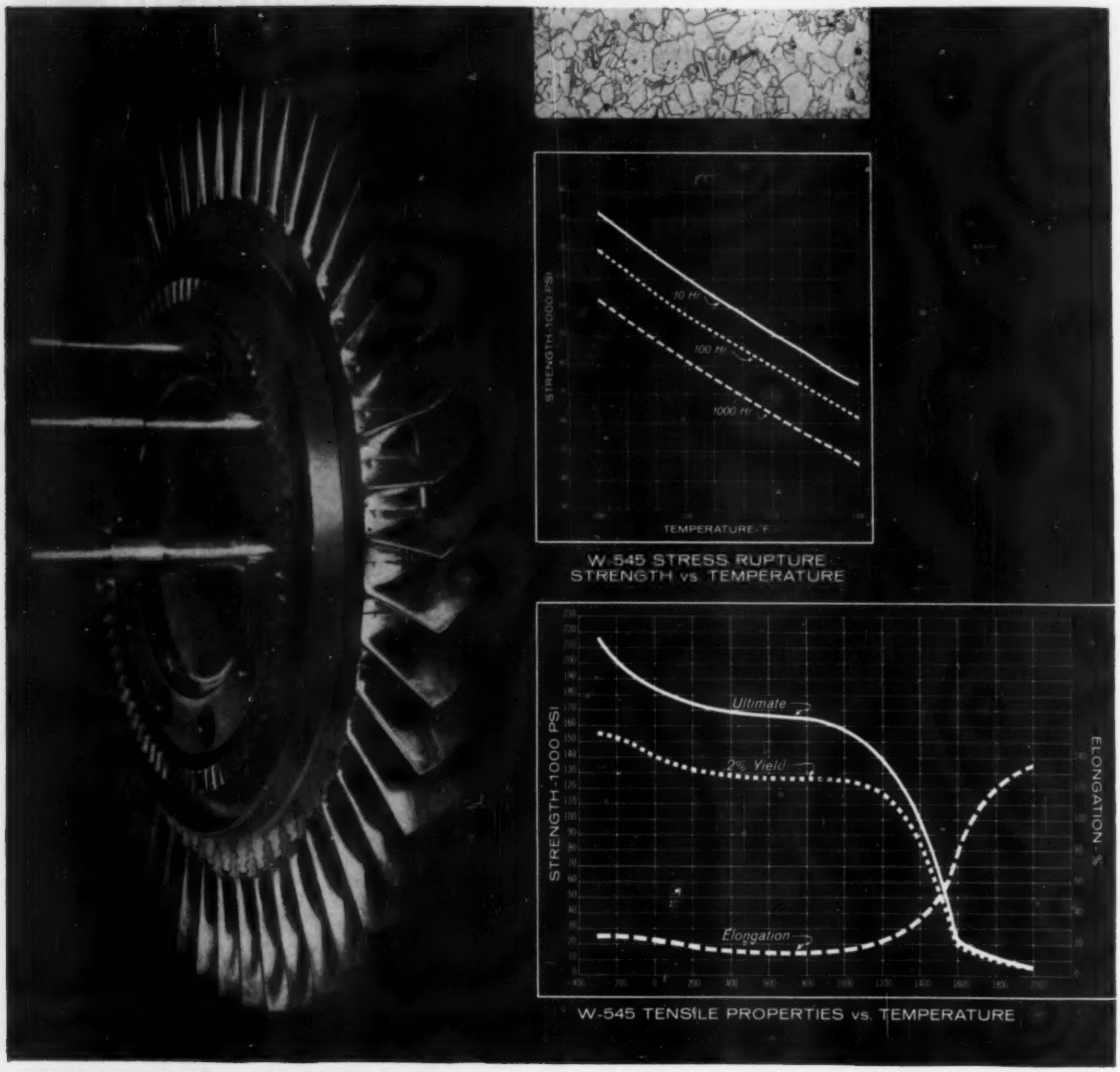
Press Breaks...

THE YEAR will be almost over when you receive this copy of our favorite magazine, and this brings to mind a bit of accounting we did a few weeks ago to compare the total number of editorial pages printed in *Metal Progress* this year with those of last year. This count was made on the basis of the fiscal year, ending on August 31, which as you probably know is the way A.S.M. operates. The 12 issues in 1959 contained 948.44 editorial pages compared with 897.63 pages in 1958. This means that the editors prepared 50.81 pages more of articles and other useful information for you last year than in the preceding year. The number of pages in our solid editorial block (this is what the editors call the front of the book where the articles run consecutively on full pages) were increased somewhat more than is reflected by the total editorial pages due to a decrease in fractional space available in the back of the book. Figures show that in 1958 our solid editorial block consisted of 640 pages compared with 724 in 1959 which represents an expansion of 84 pages in the article section in the front of the book. We will probably prepare close to 1000 pages of articles for you in the new year. With so much going on in metallurgy and metalworking these days, sometimes we have to restrain ourselves to keep *Metal Progress* within reasonable bounds.

As this column goes to press, we are busy with our first issue for the new year which you will recall is devoted to an International Review of Metallurgy and Metalworking. This means your January *Metal Progress* will be the culmination of a lot of effort on the part of the editors to bring you news of outstanding engineering developments in metals from all over the world. A sneak preview reveals such topics as Progress in Metal Forming in England ... Making Steel Castings in Switzerland ... High-Temperature Alloys in Russia ... Bright Anodizing Alloys in Canada ... Electropolishing Columbium and Tantalum in Norway ... High-Temperature Research in Europe and Asia ... Sponge Iron in Mexico ... Welding and Testing Developments in Germany and many more.

The picture below of our new Headquarters at night is a fitting way for us to say *Merry Christmas* and we hope you will visit us in our new home during 1960.

THE EDITORS


STRENGTH-1000 PSI
10 Hr
100 Hr
1000 Hr
TEMPERATURE-°F
W-545 STRESS RUPTURE
STRENGTH vs TEMPERATURE
STRENGTH-1000 PSI
Ultimate
2% Yield
Elongation
ELONGATION-%
W-545 TENSILE PROPERTIES vs. TEMPERATURE

Metal Progress

PUBLISHED BY AMERICAN SOCIETY FOR METALS
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Other activities of American Society for Metals:

Publishes *Metals Handbook*, an encyclopedia of metals; *Metals Review*, news magazine; *Review of Metal Literature*, abstracting service; *Transactions*, scientific annual; Career technical books on metals.

Educational activities: Operates National Western, and Southwestern Metal Congresses and Expositions; prepares and administers courses for Metals Engineering Institute for home, in-plant or American Society for Metals Chapter study.

READERSHIP Eastman RESEARCH

Metal Progress is available on microfilm from University Microfilms, Ann Arbor, Mich.

lead in rocket case construction

PRATT & WHITNEY AIRCRAFT SURVEY OF ROCKET CASE MATERIALS

GENERAL PROGRAM

The goal: "A material capable of reaching 300,000 psi yield strength in steel, with a considerable development margin."

The result: "While this goal had to be modified for steel cases, we have successfully tested small scale titanium cases with a steel equivalent yield strength well beyond the 300,000 psi point."

Conclusions: 1. "By exercising reasonable care, the development of full scale (steel) cases at 240,000 psi is perfectly feasible.

2. "Small scale (titanium) cases have been burst at stress levels as high as 260,000 psi . . . we are convinced that reliable cases can be manufactured (from titanium) at yield strength levels of 180,000 psi and over . . . at 180,000 beta titanium is equivalent to steel at 280,000 psi.

"At 200,000 psi beta is equivalent to steel at 320,000 psi. 200,000 psi beta is possible and obviously would mean substantially increased payload to the moon or out into space."

SPECIFIC COMPARISON: Strength

Alloy	Density	Practical Yield Strength (5% elongation)
Ti-6Al-4V	0.161#/in.³	155 ksi = steel at 270 ksi
Ti-13V-11Cr-3Al (Beta)	0.175#/in.³	180 ksi = steel at 280 ksi
		190 ksi = steel at 305 ksi
		200 ksi = steel at 320 ksi

Burst Test Results show titanium has provided consistent burst strengths of 235,000 psi — a burst strength/density ratio of 1,340,000. Failure occurs in the wall of the case itself — not the weld zones. Titanium cases do not fragment.

SPECIFIC COMPARISON: Corrosion Resistance

Steel: "All of the low-alloy constructional steels which have been discussed are subject to general rusting and, far more serious, to pitting type corrosion during machining, welding, heat treatment, pressure testing and final storage. Corrosion pits can act as severe stress-raisers and, in conjunction with hydrogen, have been demonstrated to cause catastrophic failure. It therefore goes without saying that pitting corrosion is a serious hazard."

Titanium: "Like other titanium alloys, the beta titanium alloy has excellent resistance to corrosion under normal atmospheric conditions, in salt water as well as in many other media.

"In considering the long-time storage problems with rocket cases—a pit in a thin-walled casing can be catastrophic — we would regard the beta titanium alloy as the outstanding material under consideration."

• Reliability and growth . . . the parallel

Pratt & Whitney Aircraft data reveal rocket-cases can *now* be built from beta titanium at strengths 17 percent greater than alternate metals, with beta titanium's strengths bounding forward under a minimum of development.

A striking parallel exists in liquid-fueled rocketry where titanium alloy Ti-6Al-4V was selected for helium storage bottles in the Atlas missile because of its strength/density ratio. Airite Products, Inc., a leading supplier of the titanium vessels, reports:

"Minor modifications in processing techniques and continuous tightening of tolerances and other variables have shown an increase from the original 5400 psig average burst pressure to the present average which is in excess of 9000 psig.

"This has been done without increasing the weight of the article by one ounce. Weight of the unit, incidentally is controlled to a tolerance of plus or minus one-half pound, on a weight of 79 pounds, and volume is controlled and guaranteed to plus or minus one percent."

While the performance of the titanium pressure vessels has been almost doubled, the price has been reduced almost 50 percent — and the missile has become operational.

• When a case fails, so does the missile

The price of completed beta titanium rocket-cases is now estimated at 2½ times the price of other metals, with titanium cases virtually in their infancy. Should the titanium cost difference remain, the pay-off would still be two-fold:

1. **Cost**: engineering time, would be greatly curtailed; expensive fuels (for example, 30 pounds of fuel are required in earlier stages for each additional third-stage pound) would be saved.

2. **Reliability**: titanium cases simply will not pit, rust, deliquesce, or become hydrogen embrittled.

Added together, these elements mean feasibility—feasibility supported by the commercial availability of the metal itself. Beta titanium alloy Ti-13V-11Cr-3Al is available from Titanium Metals Corporation of America at these lead times: billet, 2-3 weeks; bar, 3-4 weeks; flat-roll, 5-6 weeks. TMCA's metallurgical experience with the alloy is yours for the asking.

For further information, write for TMCA Data Bulletin *All-Beta Titanium for Solid Rocket Pressure Chambers*. Extensive welding information is included.

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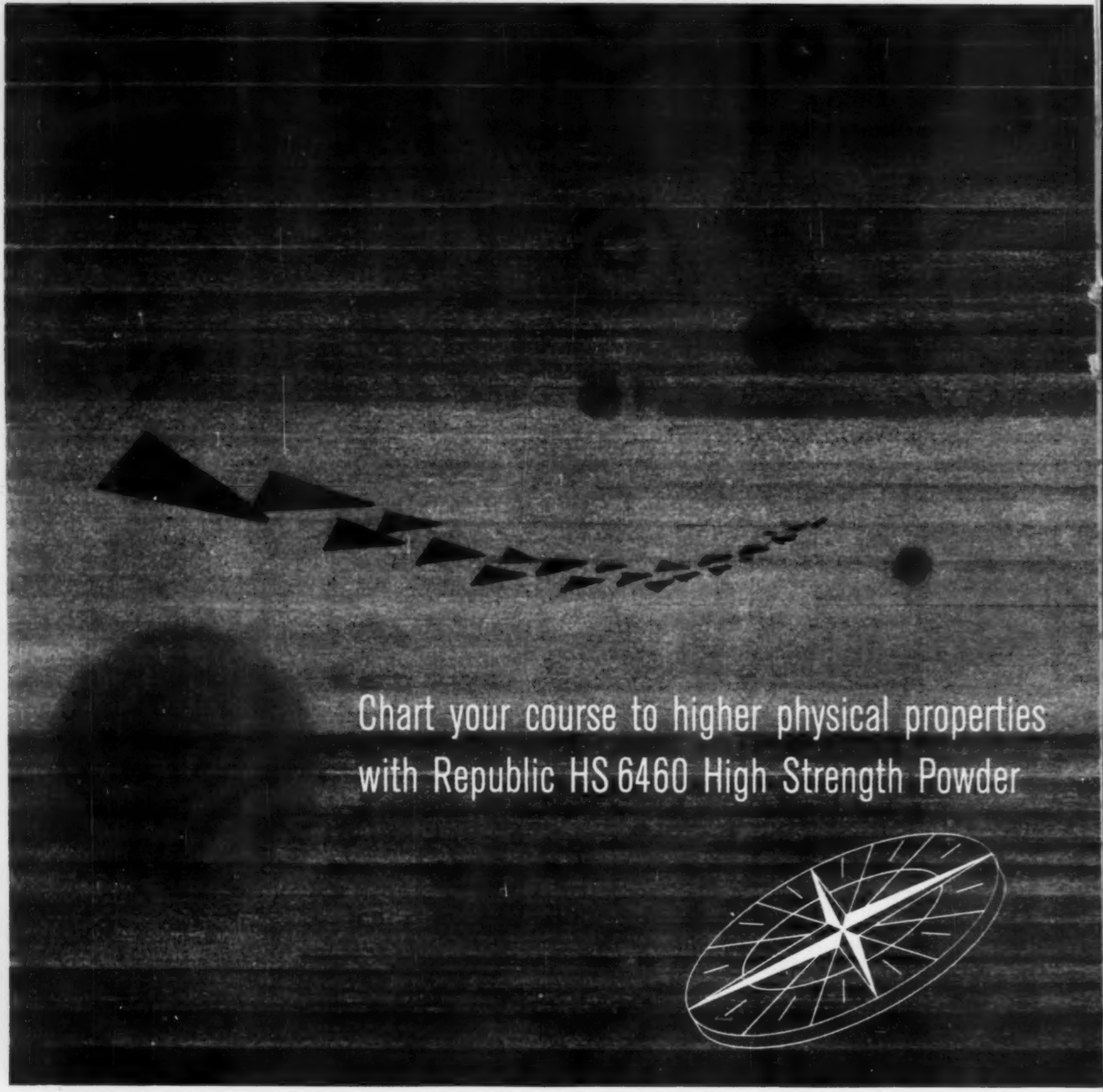

Now you can produce *higher strength, higher stressed* parts on existing production equipment with Republic HS6460 High Strength Powder.

HS6460 is a soft, alloy powder with excellent compressibility. It makes possible higher tensile strengths than ever before achieved with ferrous powders. Provides a minimum tensile strength of 60,000 psi at 6.4 density as sintered —100,000 psi after heat treatment. Excellent carbon compatibility enhances its ability to be heat treated.

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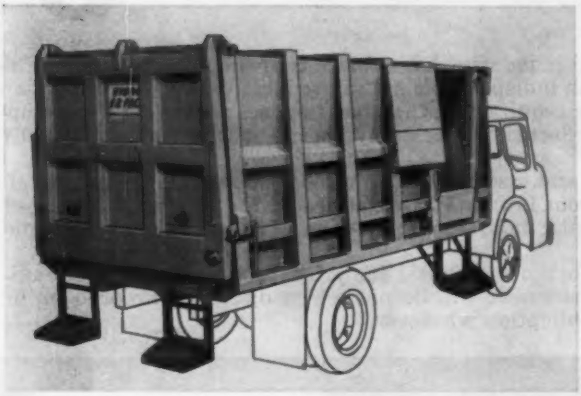
For technical data on HS6460 High Strength Powder, including fatigue and impact test results, mail the coupon.



HIGH STRENGTH STEEL SOLVES WEIGHT PROBLEM in Hydro E-Z Pack enclosed truck bodies, manufactured by Hercules Galion Products, Inc., Galion, Ohio, for haulers of refuse and garbage. Tough, strong, lightweight Republic "50" High Strength Steel allows an E-Z Pack unit to be carried on a chassis as small as a two-ton truck. Reduced weight permits increased payload—fewer trips to the dump. High Strength Steel withstands the heavy compressive force of packer blades, allows tight compaction of loaded materials. Long, dependable service is assured by high resistance to the corrosive and abrasive action of refuse. Write for full facts on Republic High Strength Steel.

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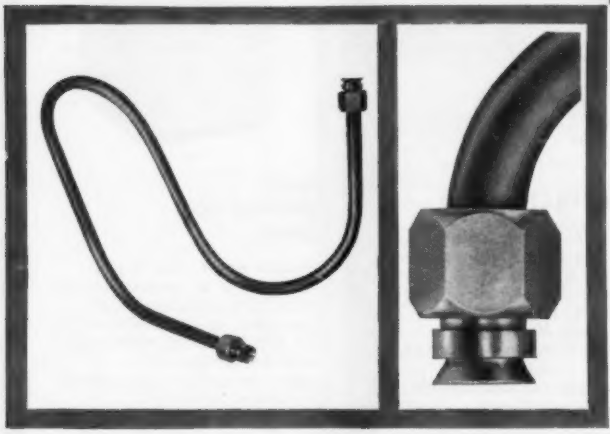

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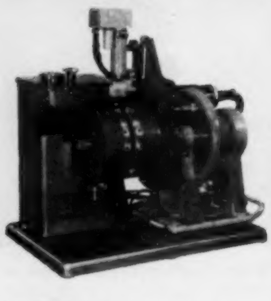
X-Ray

The use of X-ray spectrography and X-ray diffraction in industry has enjoyed tremendous expansion in the past decade, and is now universally recognized as an indispensable aid in product quality and production control. Traditionally, metallurgical applications and requirements have set the pace for the rapid development of X-ray instrumentation—and is in fact reflected in the many special instruments specifically designed to cope with metals industry problems.

This parallel progress has been of paramount and essential aid in the development of many metallurgical processes and alloys. Applications range from intimate explorations of the atomic structure of elements—on a single laboratory specimen to automatic analyses of quantities of samples—through rapid measurements of claddings or plating thickness.

One of these X-ray processes are applicable to most metallurgical analytical problems and can be engineered to specific requirements. Our Technical Department will be pleased to discuss your problem or show you how to save processing dollars, without obligation whatever.



UNIVERSAL VACUUM X-RAY SPECTROGRAPH

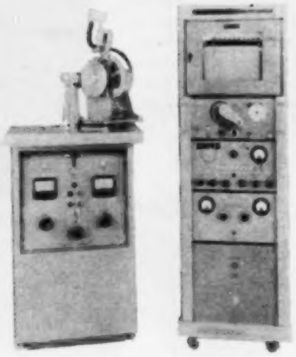
The new Norelco Universal Vacuum X-ray Spectrograph embodies maximum inherent flexibility by permitting operation with air, helium or vacuum. Evacuating the X-ray path provides higher intensities in the entire range of elements from #12 (magnesium) through #30 (zinc), and is of particular importance in the range of elements up to sulphur (#16).

New design features include:

SPECIMEN CHANGER — permits simultaneous top loading of four multi-purpose specimen holders and successive analysis of samples without breaking vacuum.

CRYSTAL CHANGER — holds two externally selectable analyzing crystals which permits an extremely broad analyzing range.

DETECTORS — Scintillation and flow-proportional detectors are both mounted on goniometer arm and are available for selective usage.



X-RAY DIFFRACTOMETER

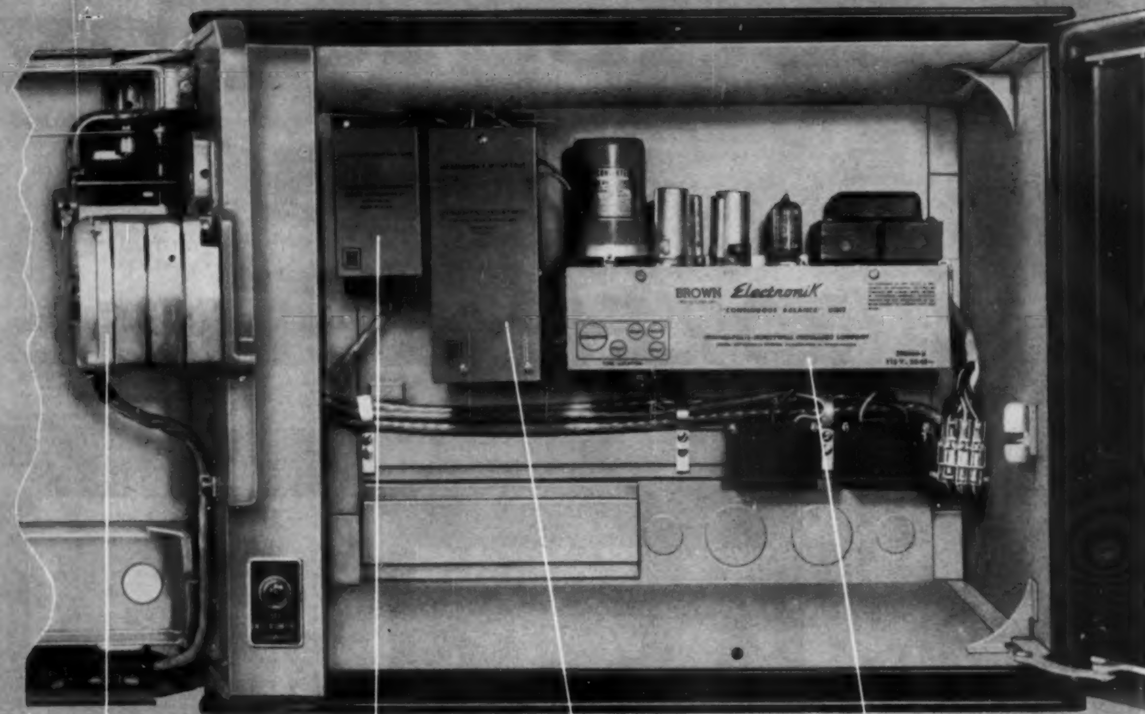
Permits automatic recording of the diffraction spectrum by the addition of a wide range goniometer and electronic circuit panel to the basic diffraction unit. High speed detectors and electronic circuitry used in place of diffraction cameras provide rapid and more accurate determinations.

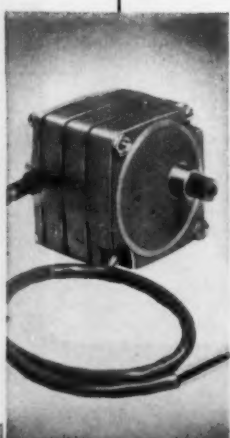
BASIC DIFFRACTION UNIT

Power source for X-ray diffraction or spectrography this fully regulated unit provides up to 50 MA and 50 KV for X-ray diffraction, diffractometric or spectrographic applications.

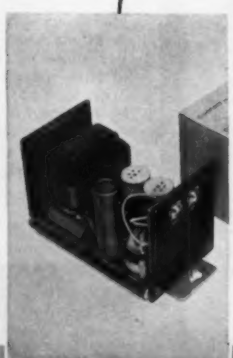
COMPLETE X-RAY SPECTROGRAPH

Permits rapid, accurate, non-destructive analysis of elements within a sample regardless of free or combined state. Chart position of the spectral peaks identify elements; quantity present is indicated by the height of the peak. A variety of special spectrographic attachments may be used—including the standard, universal-vacuum, and bulk. The latter is indicated with large slug specimens up to ten inches wide and two inches thick.

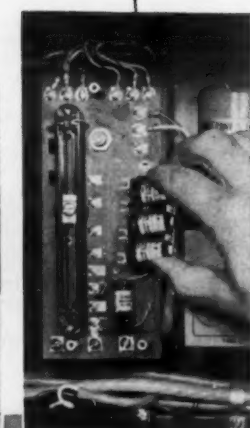




Servo Motor has sectional housing, leakproof oil wick, printed circuits for simplified servicing. Any major part can be replaced in 2 minutes.



Constant Voltage Module—Uses Zener diodes and an ambient temperature compensator to replace standardizing mechanism.



Measuring Circuit Module—Contains easily-changed range spool panels and vernier adjustment. Range is changed simply by replacing screw-clip panels of fixed resistors.

Amplifier Module—Quick-connect design permits fast, easy removal for servicing and replacement. Circle shows quick connect plug.

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New modular design...

makes *ElectroniK* potentiometers easier to use and maintain

Now, four great new features add new operating and servicing ease to all *ElectroniK* circular and strip chart potentiometers.

- **New servo and chart drive motors are sectionalized so that any major part can be replaced in two minutes.**
- **A new constant voltage unit replaces batteries, standard cells and standardizing mechanisms.**
- **A new measuring circuit, with quick-change range spools, simplifies range changing and reduces stray pickup.**
- **A quick-connect feature lets you remove the amplifier for service and replace it quickly.**

Now, modular design is combined with the traditional precision of *ElectroniK* potentiometers, to give you a greater value than ever in accurate, dependable measurement and control.

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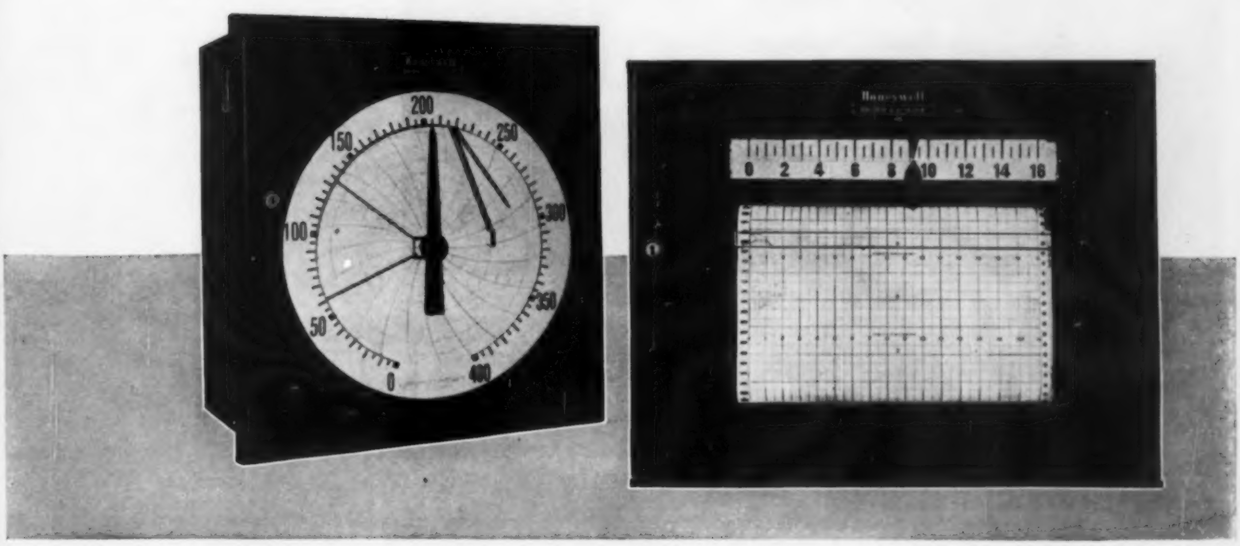

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*Cost Saving,
Time Saving
ALODINE 1200S
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Protects Aluminum
Best!*

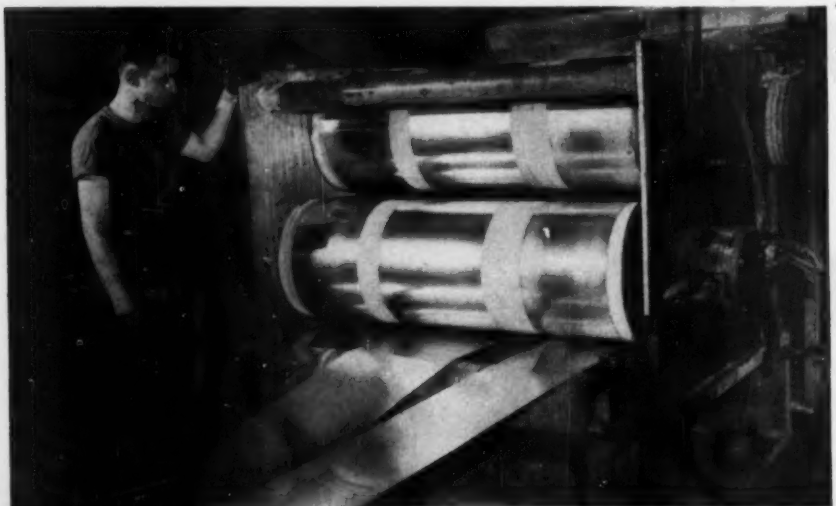
IN LESS TIME—ALODINE 1200S provides increased chemical activity for dramatic reduction in processing time . . . up to 50% in most cases! You get far faster processing than ever before, with the same high quality protection!

WITH LESS EQUIPMENT—You can install an ALODINE 1200S system quickly and conveniently, *without resorting to mechanical bath maintenance!* That means no dangerous, time consuming checking routines with the possibility of bath contamination always present!

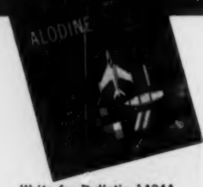
AT LESS COST—ALODINE 1200S can be processed through continuous dip in the same time cycle other conversion coatings require for continuous spray lines! This dip technique reduces initial equipment costs, slashes maintenance costs to a minimum and allows aluminum fabricators to utilize conversion coatings more frequently for a wider range of product applications! Whatever the application method—brush, dip, continuous strip or spray—ALODINE 1200S may be the answer to your production problems.

FOR MORE FLEXIBILITY—Most important, its ease of operation, safety in use and versatility enables ALODINE 1200S to answer one of the most perplexing problems inherent in providing corrosion protection and paint bonding qualities for aluminum—the problem of constant, uniform quality. ALODINE 1200S is qualified under Government Specification MIL-C-5541.

Investigate cost saving, time saving ALODINE 1200S today! And whenever you have a chemical finishing requirement for aluminum—any type of aluminum—there's an ALODINE process available to protect or decorate the metal, and anchor the paint finish more securely.



Typical ALODINE 1200S strip line installation at ALSCO, INC. Strip from aluminum coil is fed into Alodine processing baths where it is cleaned, rinsed, deoxidized, rinsed, coated with ALODINE 1200S, rinsed and given a final acidulated rinse. Strip is then rewound, roll coat painted, roller formed into final shape, backed, inspected and packed for final shipment.



Write for Bulletin 1424A describing use of Alodine for aluminum fabrications of all types.

AMCHEM

ALODINE 1200S

another chemical development of **AMCHEM PRODUCTS, INC., Ambler 23, Pa.**
(Formerly American Chemical Paint Co.)

Detroit, Mich. • St. Joseph, Mo. • Niles, Calif. • Windsor, Ont. Amchem and Alodine are registered trademarks of Amchem Products, Inc.

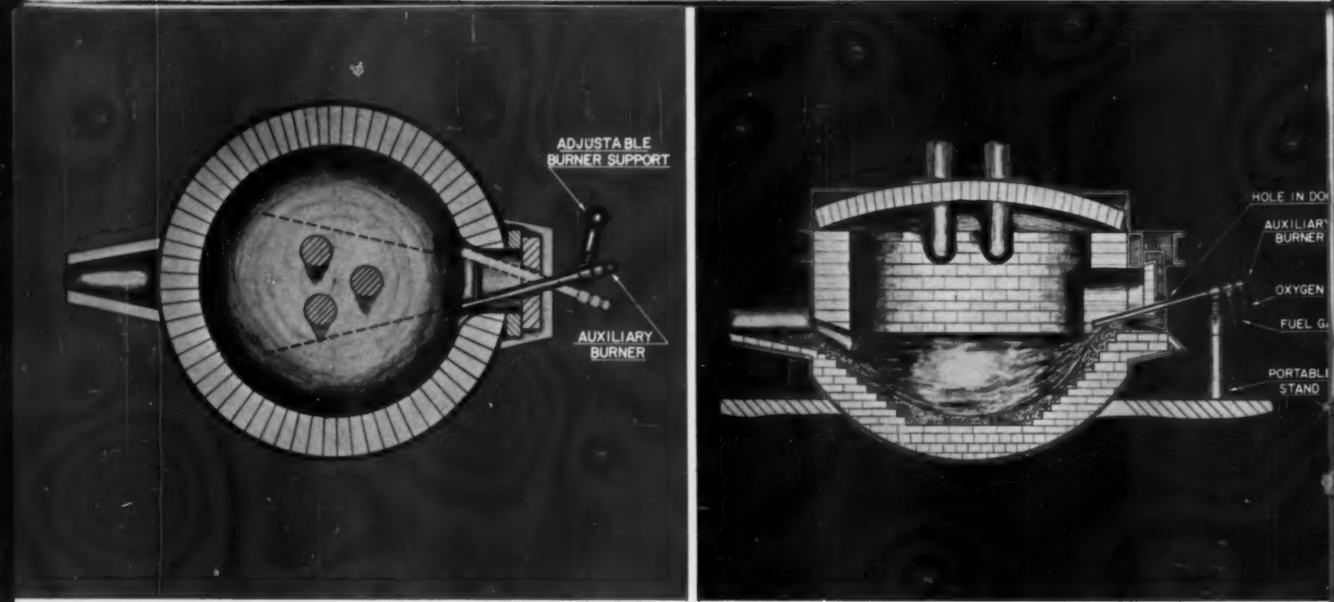
Vol. 6 No. 3
December 1959

NATIONAL CARBON COMPANY'S

CARBON AND GRAPHITE NEWS

A NEW CONCEPT FOR USING OXYGEN IN ELECTRIC FURNACES

By G. W. Hinds



Figs. 3 & 4. Top and side views of a typical door burner installation designed by LINDE for electric arc furnaces having a capacity under ten tons.

A NEW CONCEPT FOR USING OXYGEN IN ELECTRIC FURNACES

G. W. Hinds

Development Engineer, Development Laboratory

Linde Company, Division of Union Carbide Corporation

Introduction

Today, more than ever before, there are many new techniques constantly under investigation to help the electric furnace industry continue to improve its competitive position. How to increase production and lower costs has been under intensive study throughout the industry. In this respect, a few electric furnace shops have experimented with air-gas burners fired through the door, roof, and into scrap buckets to pre-heat scrap both before and after charging to utilize lower cost heat and to increase production.

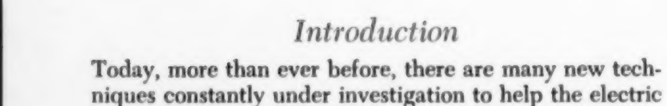
Recently, a practical process has been developed by Linde Company for using oxygen to assist scrap meltdown in electric-arc furnaces. This process utilizes newly-designed oxygen-fuel gas "door" or "wall" burners to speed this operation.

Based on production tests, the use of this equipment has resulted in these major advantages:

1. PRODUCTION HAS INCREASED FROM 15 TO 20 PER CENT.
2. POWER CONSUMPTION HAS DECREASED 15 TO 20 PER CENT.
3. THE USE OF OXYGEN HAS RESULTED IN UNIFORM SCRAP MELTING RATES.
4. ELECTRODE CONSUMPTION REMAINS NORMAL WITH THIS PROCESS.

Oxygen-Gas Burner for Rapid Scrap Meltdown

In early development, it was known that oxygen should reduce scrap meltdown time. On this basis, tests were conducted wherein oxygen and gas pipes were positioned at all angles to each other from parallel to perpendicular for post mixing. A concentric burner design shown in Figure (1) was found to perform best. With this type of



Test Results

burner, oxygen flows through the center pipe while natural gas flows through the surrounding annular pipe. This equipment became the basis of present burners known as "door burners" and "wall burners."

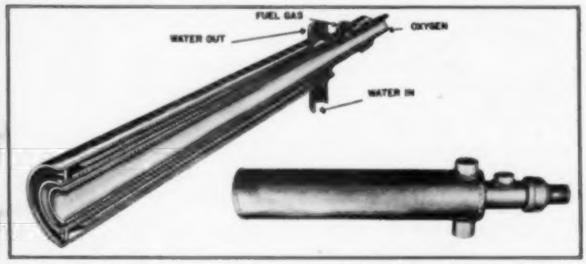


Fig. 1. Linde Company concentric burner design which is basis for door and wall burners.

Door Burners

A typical door burner is shown in Figure (2). Although the burner as shown is not water-cooled, a water-cooled jacket may be provided.

Installation of this burner is relatively simple. It is only necessary to support the burner through a hole in the door so that the burner can be directed as required at scrap between the electrode and furnace wall as shown in Figures (3) and (4) on opposite page. In initial tests, the burner can be supported through a partially opened door.

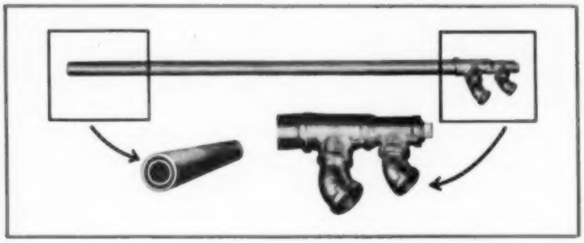


Fig. 2. A typical door burner designed by LINDE.

Wall Burners

A typical water-cooled wall burner of Linde's design is illustrated in Figures (5) and (6) shown below. Generally, three or more burners of this type can be installed on furnaces ranging in capacity to 200 tons or more.

A primary consideration for the successful use of wall burners is that their installation should be practical and should not be complicated. Combination wall port and water-cooled burners have been found to give satisfactory maintenance-free operation. *A special feature of their design is that separate port coolers are not required.* The non-cooled oxygen pipe can be quickly removed for tip cleaning if necessary. The burners are positioned tangentially in the wall and directed downward at an angle of approximately 15° from the horizontal. This is to allow direct scrap contact for as long a period as possible.

Controls

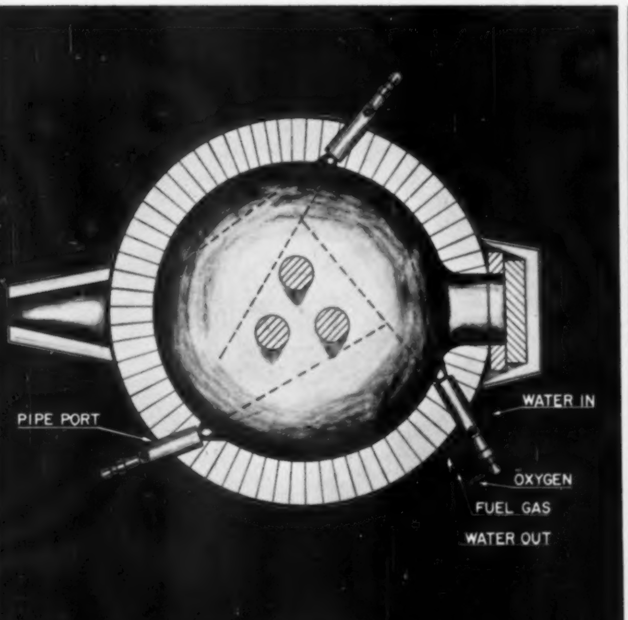
To supply fluids to the burners, it is necessary to install water, oxygen and natural gas manifolds around the furnace shell. A water pressure of 20 to 30 p.s.i. is maintained at the burners.

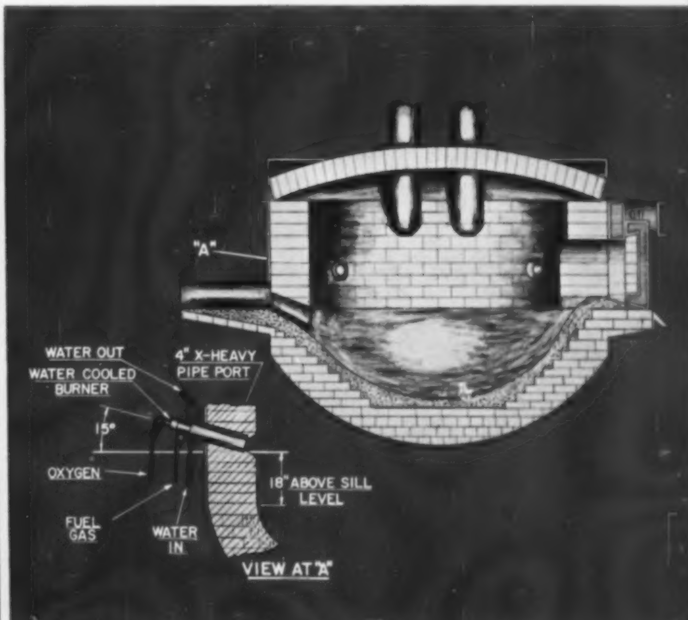
Every auxiliary burner furnace installation should include a control panel near the furnace as shown schematically in Figure (7). Automatic safety valves shut off the flow of both oxygen and fuel gas in the event that abnormally wide pressure variations occur.

Operation

Auxiliary burners for scrap meltdown are turned on after the furnace has been charged. They are then operated continuously for as long as they can be effective on scrap remaining in the furnace. The precise moment for turning on the burners varies with charging practice. In door charging practice, it is as soon as there is sufficient scrap in the furnace. In top charging, the burners are turned on either slightly before or immediately after dropping the charge into the furnace.

Figs. 5 & 6. Top and side views of a typical wall burner installation designed by LINDE for electric arc furnaces having a capacity of ten tons and over.





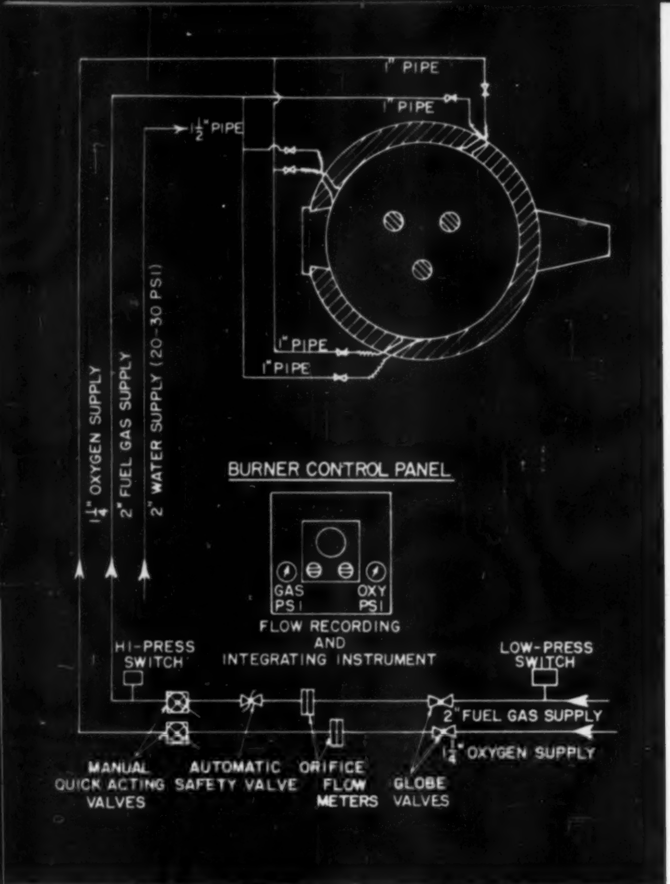


Fig. 7. Schematic view showing burners and controls for a wall burner electric furnace installation by LINDE.

Flow rates are established in accordance with data in Table (1) by appropriate adjustments at the control panel. When starting on a new charge in wall burner practice, the flame should be adjusted to a minimum for a few minutes to allow time for the burner flames to cut into the scrap directly in front of the burner ports. This will prevent flame deflection against the wall.

Numerous tests on all size furnaces indicate normal refractory and electrode consumption. With water-cooled wall burners, the brick lining around the burners remains intact with very little wear.

Test Results

Principal effects of the auxiliary meltdown oxygen-gas burners are faster meltdown time and lower power consumption. Several important effects other than these are:

1. Scrap is melted uniformly away from the walls and banks early, thereby reducing the possibility of broken electrodes due to scrap cave-ins. Furnaces with low capacity transformers have difficulty melting scrap around the edges of the bath. The scrap hangs in ledges around the walls and frequently falls into the bath late in the heat, causing unexpected analysis changes.
2. Burners can be directed toward furnace "cold spots" to accomplish uniform meltdown and to eliminate scrap hangers.
3. Burners can be operated during each back charge. Burner operation during periods of "power-off" is considered exceptionally worthwhile since the flame continues to heat and melt the scrap.
4. Burners can be operated on the cold charge in newly relined furnaces prior to arrival of furnace crew.
5. Light, voluminous scrap melts rapidly rather than hanging up in a mass.
6. Furnace overtime can be reduced.

Effect on Production

Tests on various size furnaces have shown unusually consistent differences between heats made with burners and heats made without burners. Figure (8) illustrates typical differences in meltdown power and meltdown time when oxygen-natural gas burners are used during the melting period of every other heat. In initial test work, the burners were operated at the oxygen-natural gas ratio of 2 to 1. This was found to result in an excessively high FeO value in the slag and low carbon values at meltdown. Near normal "melt-in" analyses were obtained by using the reducing ratio of 1½ to 1.

Evaluation tests in a 50-ton door charge furnace having two back charges produced the following results when two burners were fired through the side door at flow rates of 10,000 cfh oxygen and 7,000 cfh natural gas each. Meltdown time was reduced 15 per cent and meltdown power decreased 19 per cent. No differences were noted in bath temperature at "melt" or in furnace yield.

Table I — Representative Oxygen and Fuel Gas Flows for Scrap Meltdown in Electric Furnaces

Type Burner	Furnace Size tons	Number of Burners	Flow Rate/Burner Oxygen cfh	Flow Rate/Burner Gas cfh	Total Flow Rate Oxygen cu. ft. per hour	Total Flow Rate Gas cu. ft. per hour
Door	1	1	3,000	2,000	3,000	2,000
	2	1	5,000	3,300	5,000	3,300
	4	1	6,000	4,000	6,000	4,000
	8	1	7,500	5,000	7,500	5,000
Wall	10	3	3,000	2,000	9,000	6,000
	20	3	6,000	4,000	18,000	12,000
	50	3	7,500	5,000	23,000	15,000
	80	3	11,000	7,500	33,000	23,000
	100	4	9,000	6,000	36,000	24,000
	200	4	10,000	6,700	40,000	27,000

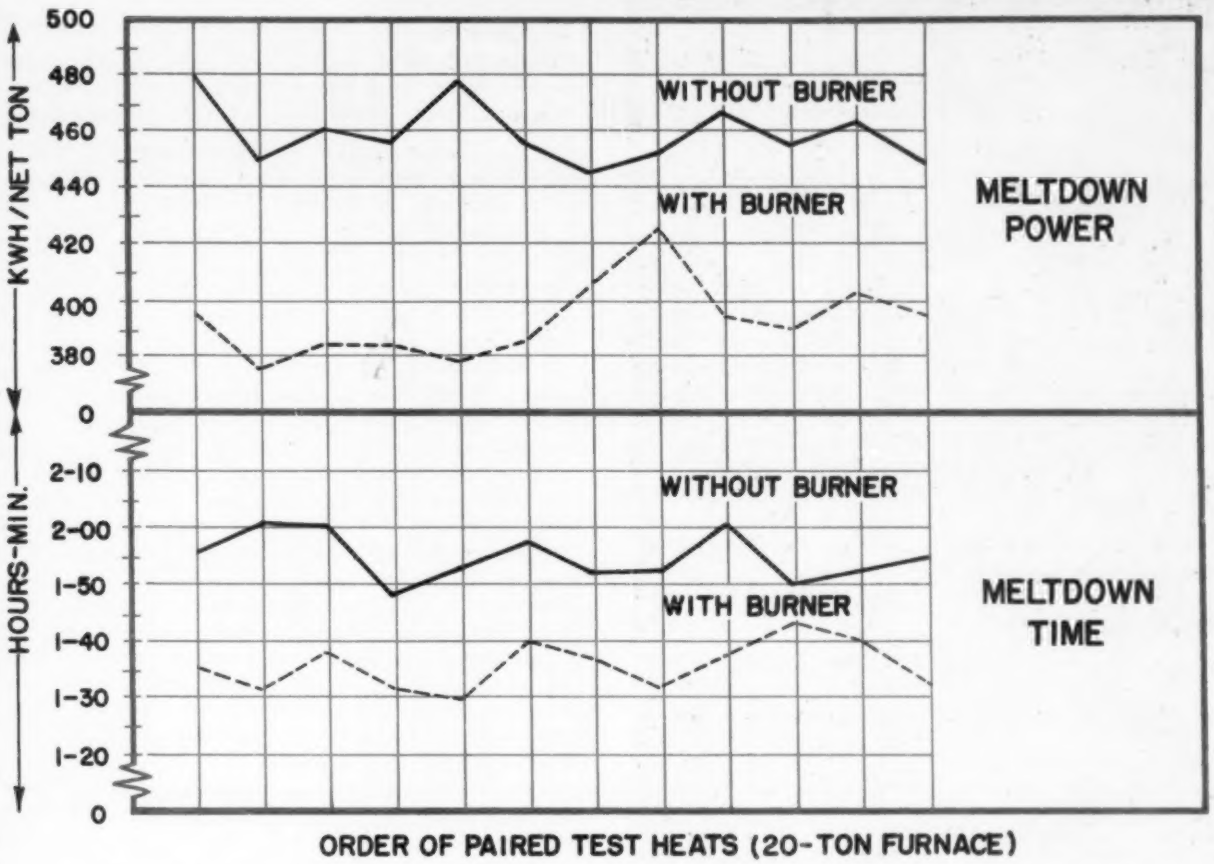


Fig. 8. Typical differences in meltdown power and meltdown time when "Linde" oxygen-natural gas burners are used during every other heat.

Single burner operation with 11,400 cfh oxygen and 7,600 cfh gas in a 20-ton top charge furnace reduced the average meltdown time 15 per cent. The fact that meltdown power was only reduced by 14 per cent is attributed to the type of scrap used. Three back charges were required.

Similar results were obtained when operating a 4-ton, top charged furnace for making low carbon steel castings and using a door fired burner for 30 minutes. The average total power was reduced approximately 15 per cent. The tap-to-tap time was reduced by 15 per cent, while the production increased by 14 to 20 lbs. per minute.

Exceptional savings have been experienced in a shop having only one 1500 KVA transformer for two 4-ton furnaces. A single oxygen-gas burner was operated through the door of one fully charged furnace, while meltdown proceeded normally in the second furnace. *On both stainless and ordinary carbon steel, power requirements were reduced by 30 per cent and heat time was reduced from 30 to 50 per cent.* Because of limited transformer capacity, the burner was operated for approximately 1½ hours before power was made available. However, for normal operation, oxygen-gas burners and power should be used simultaneously.

Conclusion

The use of oxygen-fuel gas burners for scrap meltdown in electric furnaces results in increased production accompanied by power savings with normal electrode consumption. In most shops, the operation of auxiliary scrap meltdown burners is of primary importance under one or more of the following circumstances:

1. When finishing capacity exceeds furnace capacity.
2. When the need exists for increased production.
3. When power supply is subject to interruption.
4. Where there is excessive furnace overtime.

Oxygen-fuel gas burners for scrap meltdown promise to fill a long standing need on the part of electric furnace operators. The lower power consumption and increased production associated with these burners can play an important role in improving the competitive position of older shops. When included in the design of new furnace installations, these burners can reduce capital expenditures while increasing production capacity.

Other Uses of Oxygen in Electric Furnaces

The previously mentioned application of oxygen-fuel gas burners will undoubtedly prove to be of practical value to the electric furnace industry. Although this application is new, oxygen itself has been employed as a tool in electric furnace practice since the Second World War. It has been used widely throughout the industry—in all sizes of furnaces from one to over two hundred tons—for refining carbon, alloy and stainless steels. In each of these operations, the use of oxygen provides increased production accompanied by substantially reduced power consumption.

In addition to the above mentioned applications, the industry has given close scrutiny to the use of oxygen for desiliconizing hot metal.

The following is a brief discussion covering the use of oxygen for these practices.

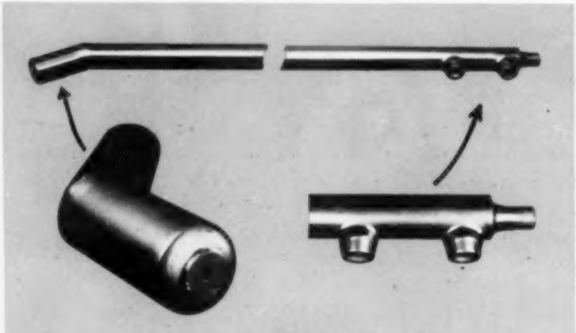


Fig. 9. Typical water-cooled oxygen jet.

Oxygen in Carbon and Alloy Steels

Oxygen has been introduced into the electric furnace bath, both by means of a water-cooled jet or a consumable lance pipe. *With the jet*, shown in Figure (9), oxygen is supplied at varying flow rates up to more than 100,000 cu. ft. per hour. These high rates are double or triple those normally used in the past. The equipment is adaptable to furnaces of all sizes. It consists of three concentric tubes.

The internal tube is used to conduct the oxygen to a copper head containing a single nozzle designed to give the required oxygen flow at a constant pressure. The head is angled to give a vertical or near vertical oxygen stream to the bath. The remaining tubes are employed to conduct the cooling water to and away from the head.

Consumable lance pipes, shown in Figure (10), have a life of 1-3 feet per minute, the higher consumption being experienced during the lancing of stainless steel melts. The internal diameter of the lance should be selected according to the pressure and flow of oxygen. Lance life can be extended 50% or more by coating with refractories.

Table 2 shows the typical lance sizes employed for various flow rates at line pressures between 125 p.s.i. and 150 p.s.i. The pressure measured at the head of the lance may be some 25 per cent lower.

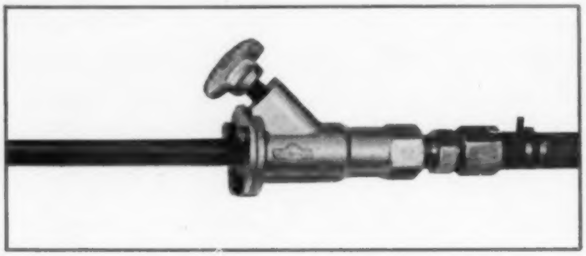


Fig. 10. Typical oxygen consumable lance pipe and holder.

FLOW RATE *Cu. ft./min.*	*LANCE SIZE* *in.*
up to 250	3/8″
250-300	1/2″
300-450	3/4″
450-600	1″

Table 2. Typical lance sizes employed for various flow rates at line pressures between 125 p.s.i. and 150 p.s.i.

Higher working pressure will obviously increase the rate of flow, but the available pressure is often restricted by the supply pressure and the distance from oxygen storage. It is customary to introduce the lance through the charging door at an angle of approximately 25° to the bath surface and to hold the tip at a depth of four to six inches below the slag-metal interface. With a little practice, the operator becomes familiar with the sound and feel of the lance and can judge when the correct immersion position has been obtained and when the lance requires feeding farther into the bath.

Requirements for Carbon Removal

The rate at which carbon can be removed from a bath of molten steel in an electric furnace depends on a number of factors. They are: initial carbon content, range in which carbon is removed, concentration of FeO in the slag, metal temperature, rate and time of oxygen input, presence of other elements, bath weight, and slag-metal contact area. Other factors peculiar to a particular furnace may also influence the rate of carbon elimination. However, one or more particular factors may have an overriding influence in different operations.

Oxygen lancing and jetting have proved capable of reducing carbon at a rate much greater than the ore boil, with no deleterious effect on furnace refractories, and in general, an improvement in steel quality. The greater carbon removal rate is accompanied by a higher temperature increment and hence a reduction in power consumption.

Oxygen in Stainless Steels

Before the introduction of the oxygen lance and jet, stainless steels were made either by melting a charge of mild steel scrap, decarbonizing with ore and adding the alloying elements in the form of very low carbon ferro-alloys, or by melting a mixture of stainless steel scrap and mild steel scrap and removing the carbon, together with a large proportion of the chromium, by means of ore. A third method was to melt mild steel scrap, remove the carbon to a low limit, add a similar weight of stainless steel scrap

and bring the charge to the required composition with low carbon ferro-chrome.

Perhaps the most important development in the use of gaseous oxygen in electric furnace practice is the introduction of oxygen lancing in the manufacture of all types of stainless steels. The technique has been successfully applied to removing carbon from steel in the presence of high percentage of chromium, enabling high quality stainless steels to be produced from 100 per cent stainless steel scrap charges. Prior to the introduction of this method, most types of stainless steel scrap had little commercial value and large quantities were dumped. This meant a considerable loss of valuable nickel and chromium to the metallurgical world which could only be replaced by virgin materials. As a result, the cost of producing stainless steels, particularly those containing nickel, tungsten and molybdenum, was extremely high.

The equipment required for decarbonizing stainless steel melts is essentially the same as that used for carbon steel production, except a higher specific flow rate is required and consequently, for an identical size furnace, a larger bore lance may be employed.

Oxygen flow rates should be as high as practicable, since the carbon will be eliminated at a greater rate with a high flow rate and a lower carbon will result. Figure (11) illustrates the difference in decarbonizing at varied input rates. This is particularly important when producing low carbon stainless steels. A high flow rate often improves refractory life since the blow is completed in the minimum time. With a prolonged blow the furnace hearth is held at a high temperature for an excessive time, resulting in increased wear.

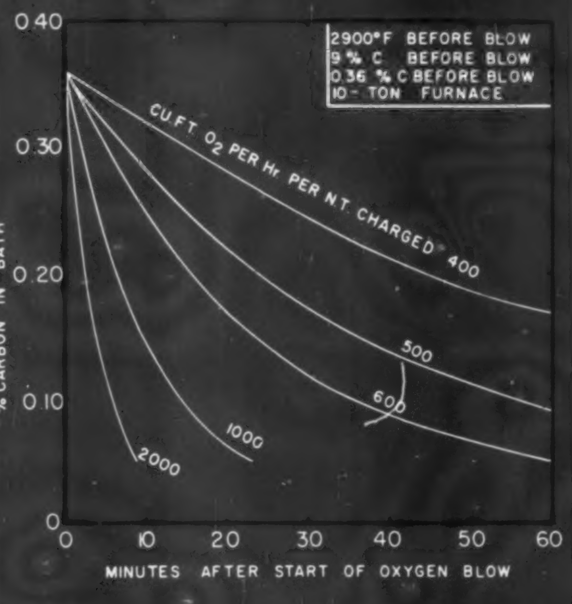


Fig. 11. Influence of oxygen input rate on progress of decarbonization.

Oxygen Desiliconization for Hot Metal in Electric Furnaces

With the continued search within the steel industry for methods of increasing production without the necessity for high capital outlay, the use of the oxygen lance or jetting probe for silicon removal from hot metal has come under close examination.

The quick removal of silicon subsequent to refining can be attractive to many operators because it increases production by reducing refining time. For example, in the electric furnace, the elimination of three-fourths of the carbon in hot metal and all of the silicon so greatly speeds melting operations that output can almost be doubled. Some furnaces in Germany are already operating with this practice, usually by blowing oxygen into the arc furnace, but good results have also been obtained in experimental heats where the desiliconizing has been accomplished prior to the charging.

Oxygen Supply and Delivery Methods

With today's increasing oxygen demand, new methods of production and distribution are constantly being sought and found. These methods not only lower the cost of oxygen, but enable it to perform in new capacities as well. The steel industry has been the recipient of the majority of these new methods. Oxygen service is actually tailored to fit the customers' needs, with the type of service determined by the volume and pattern of oxygen use.

The various methods of supply that service all steel plant activities can be broken down roughly into four categories. They are: on-site tonnage plants, "Driox" oxygen (liquid delivery and storage), "Cascade" oxygen (manifolded gas receivers), and cylinders.

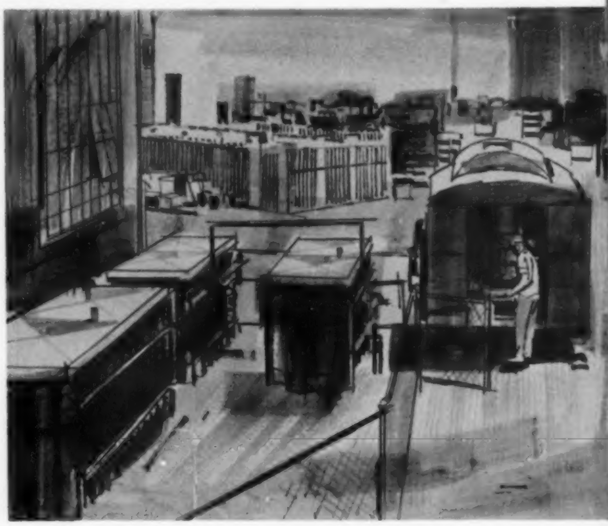
On-Site Plant

This is a gaseous-oxygen producing unit which, if installed in conjunction with a liquid oxygen storage system and a dependable source of shipped-in liquid oxygen, is most economically installed as a single production unit. Otherwise, reserve or standby units are needed, full or half-size, depending on the degree of continuity of supply that is required. The plant is built on, or very near the user's property, and is usually provided, installed, operated and maintained by the oxygen supplier. The user generally provides utility services to the plant and the oxygen distribution pipelines. The on-site oxygen producing unit can be made to produce oxygen with capacities ranging from several tons per day to hundreds of tons per day. Except under very unusual circumstances, it is not economical to install an on-site plant for a requirement of less than 10 tons per day (7 million cu. ft. per month). Because it is not practical to store more than several hours output from an on-site plant, they are generally only installed where operations are conducted on a 15-21 turn per week basis.

On-Site Oxygen Plant

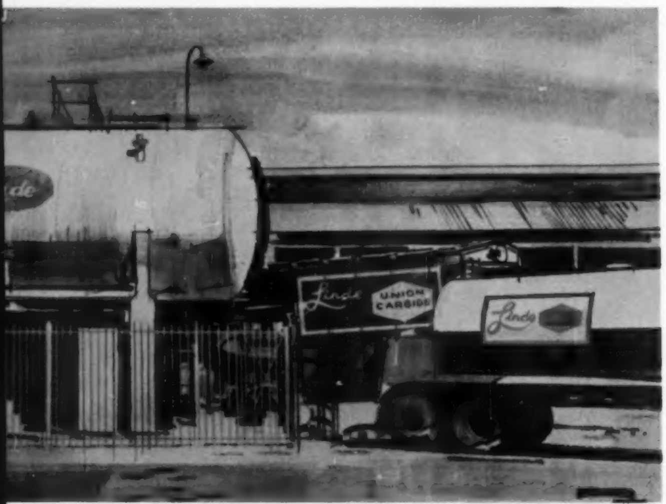
Liquid Delivery—Gas Storage

Oxygen is delivered into high pressure manifolded receivers from a liquid transport truck. The liquid oxygen is converted to gaseous oxygen by special truck-mounted converters as it is being delivered from transport truck to the manifolded receivers. This system is generally used when requirements are less than 400,000 cubic feet per month.



Liquid Delivery—Liquid Storage

With this method, mass-plant produced liquid oxygen is transported by truck or railroad tank car and stored as a liquid at the user's location. When it is needed, the oxygen is automatically converted to gas under pressure and carried through the user's pipelines to the various points of operation. It is ideally suited for the user whose requirements are intermittent, and can be provided for virtually any volume.



Cylinders

Cylinders range in size from units that hold as little as 80 cu. ft. to units containing as much as 244 cu. ft. They are portable and are used almost entirely for maintenance in the plant.

The newest development in cylinder supply is the liquid oxygen container developed by Linde Company in 1955. This cylinder is roughly the size of a 55-gallon oildrum and holds the liquid equivalent of 3,000 cubic feet of oxygen gas. Liquid oxygen is converted to gas, as needed, by equipment built into the cylinder.

All of these four methods of oxygen supply are utilized by the steel industry. As was previously mentioned, each steel plant's oxygen requirement is the key to the type of oxygen delivery or on-site unit it receives. It may be economically sound for a large, steady customer of oxygen to employ an on-site oxygen-producing unit. On the other hand, a plant with a smaller or intermittent oxygen consumption can realize the same economic advantage through delivered oxygen.

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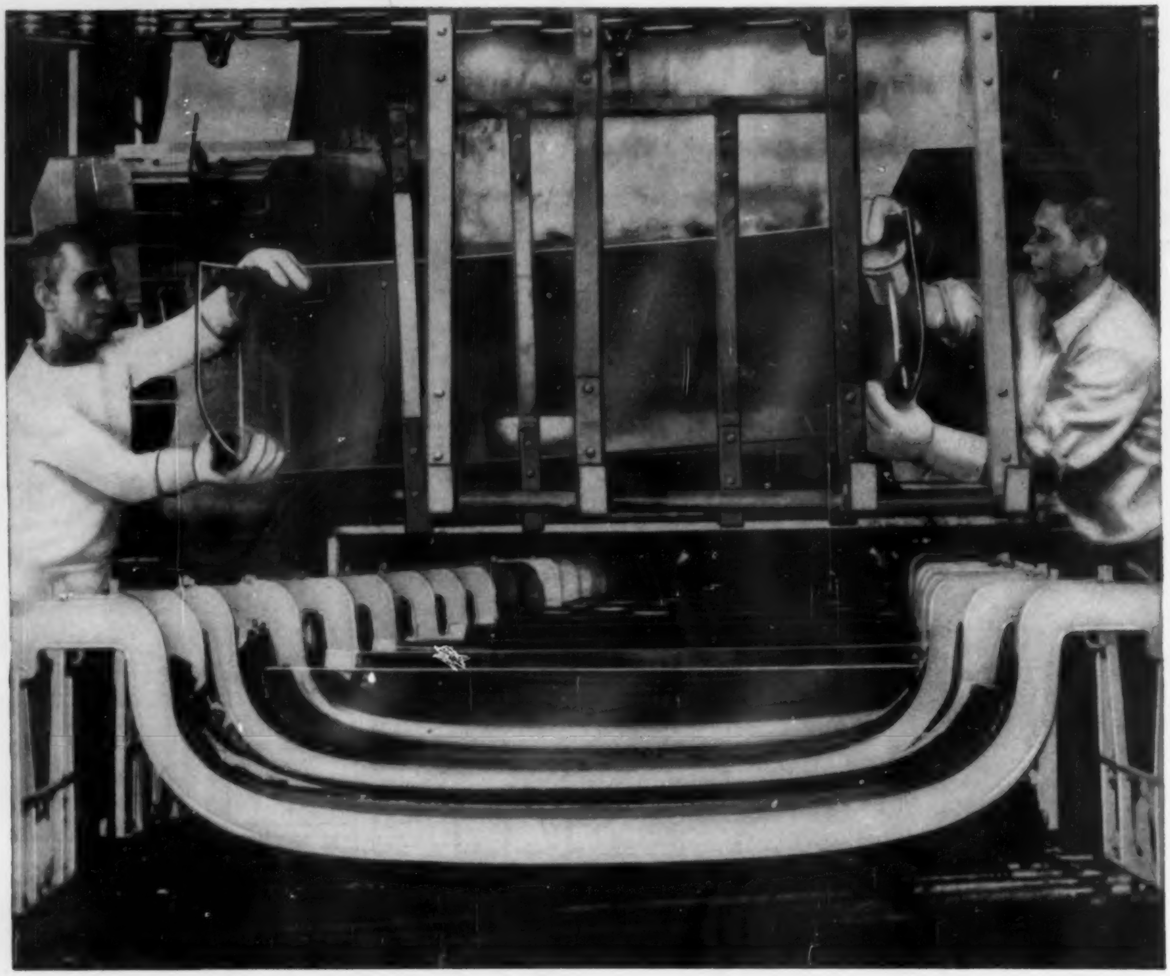

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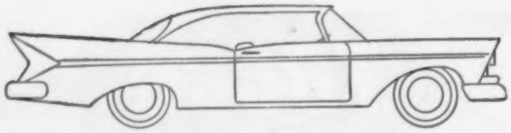

With nearly 7,000,000 cars being produced annually, the increased use of glass has demanded major production improvements in the manufacture of new panoramic windshields and back-lights.

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INTRODUCING

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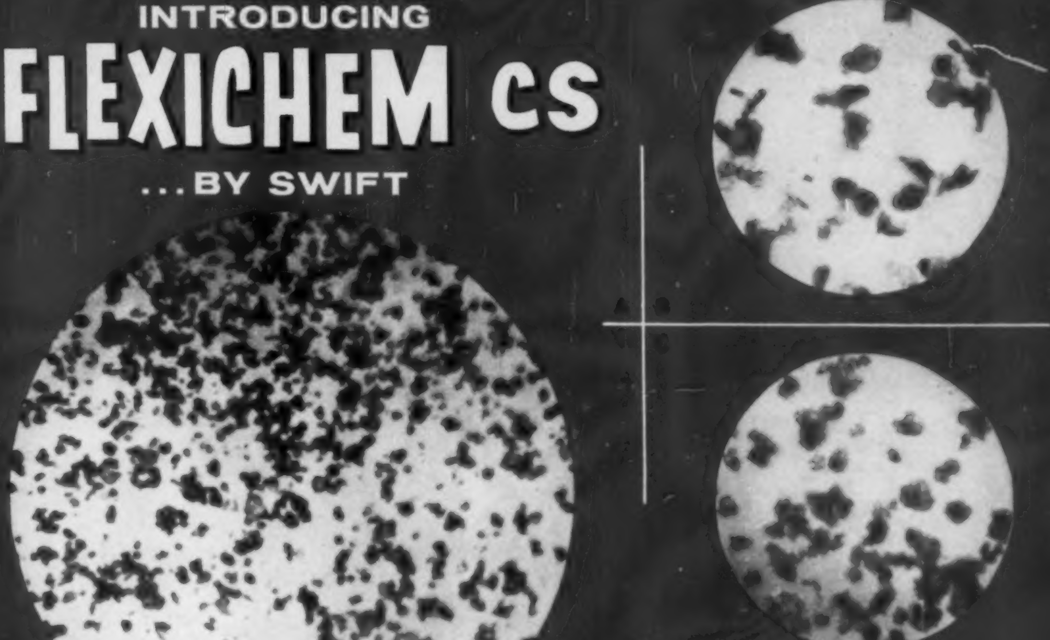

225 x magnification
Scale 1 mm = 4.4 microns

The photo micrographs indicate how FLEXICHEM CS (A) compares in size and uniformity to typical samples of commercially available 325-mesh calcium stearates (B and C).

New, extra fine calcium stearate promotes surface coverage

FLEXICHEM CS is a new impalpable calcium stearate of such fine particle size that it defies measurement by usual screening methods. Its average particle size is 5 to 7 microns while maximum size will range to only 20 microns.

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In addition, FLEXICHEM CS contains less than 0.6% moisture, is extremely low in water soluble salts, and has less than 0.2 PPM of combined arsenic and lead. Look over its other properties on the chart—then write for details on a trial or sample quantity of Swift's new FLEXICHEM CS.

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FLEXICHEM CS

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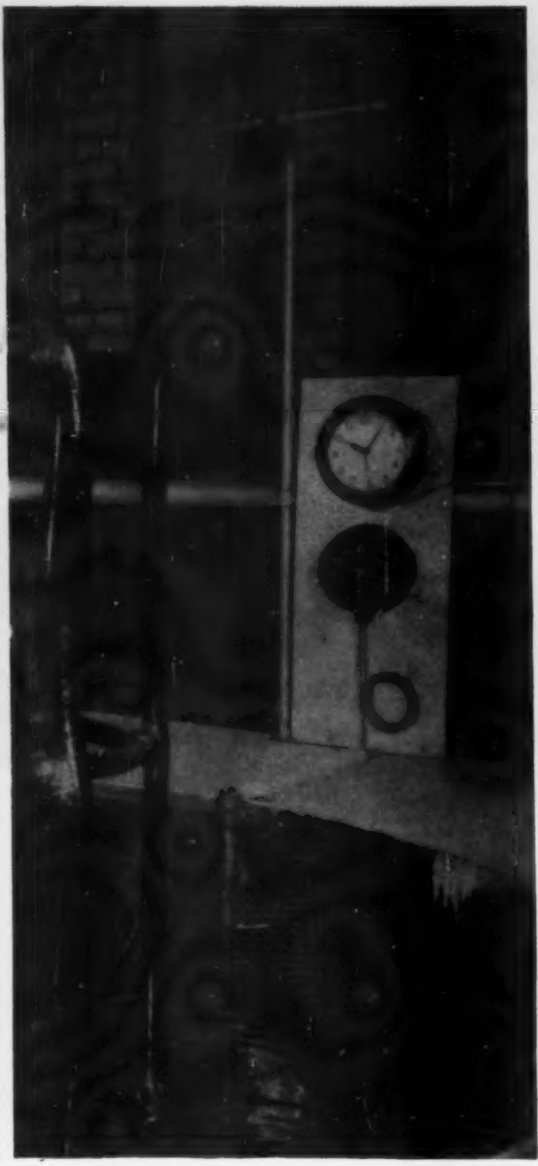
Physical form:	Impalpable powder
Particle size:	20 microns maximum
Color:	White
Formula:	$Ca\ (C_{18}H_{35}O_2)_2$
Odor:	Bland
Bulk density:	20 lbs. per cu. ft.
Melting point:	147°-149° C.
Moisture:	0.6%
Iodine number:	2 maximum
Solubility:	Insoluble in water, alcohols, esters and ketones. Slightly soluble in hot benzene, toluene, xylene, carbon tetrachloride, vegetable and mineral oils. Soluble in hot pyridine.

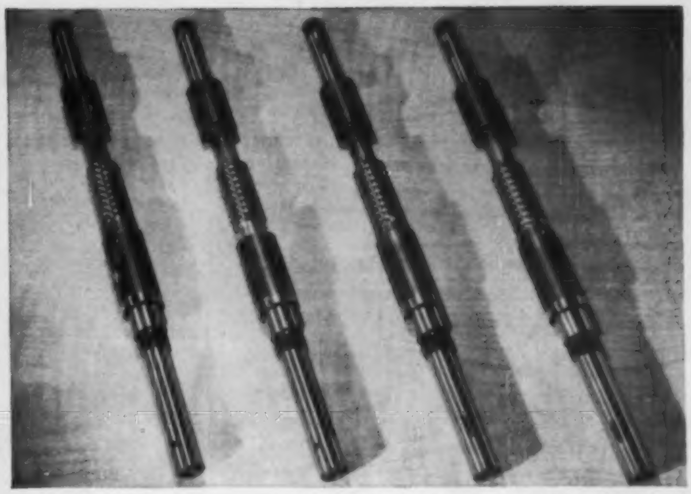
For further details, write for Bulletin 42.

Swift
105TH YEAR

S-64

To Serve Your Industry Better





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Stanley J. Kovac, left, Chief Production Engineer of Iron Fireman Manufacturing Company, shows T. F. Irving, Gulf Sales Engineer, an Iron Fireman Rotary Oil Burner, in which the components are driven by worm shafts.

One-third less distortion and deeper, more uniform hardening of worm shafts is the payoff with Gulf Super-Quench in this circulating overflow quench bath at Iron Fireman Manufacturing Company, Cleveland, Ohio.

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Machine duplicates actual stress-and-rest conditions

Flexural stresses of varying magnitude and sequence are delivered to material specimens and assemblies by this RIEHLE-LOSENHAUSEN fatigue testing equipment which simulates functional fatigue conditions. The basic system consists of a control console, a pulsator, a programmer and separate loading cylinders.

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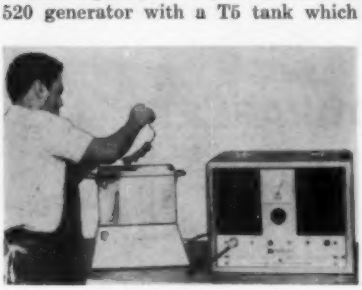
For further information circle No. 1296 on literature request card, page 48-D.

Ultrasonic Cleaners

A new line of multipower ultrasonic cleaners has been announced by Acoustica Associates, Inc. The multipower transducer design compresses piezoelectric ceramic material between two solid metal sections, providing an increase in ultrasonic cleaning power. More intense ultrasonic vibrations are produced per watt of applied energy, producing greater cavitation or agitation in the liquid. Three standard systems include Model DR 252 generator with a T3 tank which provides an average power output of 250 w. and a tank capacity of 3 gal.; Model DR 520 generator with a T5 tank which

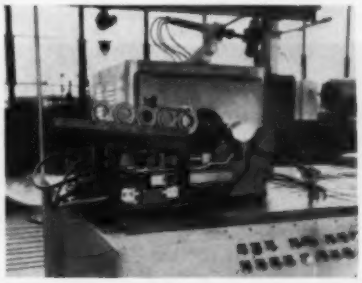


provides an average power output of 500 w. and a tank capacity of 5 gal.; and Model DR 1020 generator with a T10 tank which provides an average power output of 1000 w. and tank capacity of 10 gal. All models operate at 20 kc.

For further information circle No. 1297 on literature request card, page 48-D.

Flame Hardening

Cincinnati Milling Machine Co. has announced a Flamatic flame heater equipped with a rotating flame head. When used to harden the bore of an automotive stater hub, this automated machine received the part by gravity from an inclined chute and located it on a fixture in front of the flame head. The flame head then advanced into the

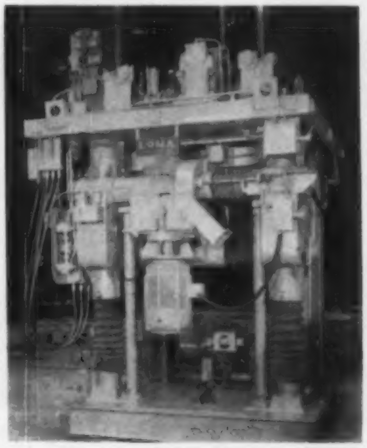


bore and revolved, heating the inside. The part was made of 1062 steel and had an O.D. of 3.940 in. and an I.D. of 2.157 in. Hardness of Rockwell C 60 to 62 was obtained to a depth of 0.125 in. At the completion of the heating cycle, the flame head retracted and the part dropped into a quench tank with a conveyor that carried the part out of the tank into tote bins.

For further information circle No. 1298 on literature request card, page 48-D.

Continuous Casting

A new continuous casting machine for copper billet and slab casting has been announced by Loma Machine Mfg. Co. The basic design of the machine also lends itself to the casting of brasses, bronzes, aluminum and magnesium alloys. The shapes produced on the unit include round piercing and extrusion billets, square wire



bars and rectangular slabs. The production capacity ranges from 3 tons per hr. for double-strand casting of 3-in. diam. billets to 10 tons per hr. for single-strand casting of slabs 5⅓ by 33 in. One feature is the underpouring method of metal flow which assures a splash-free entry of clean metal into the mold cavity.

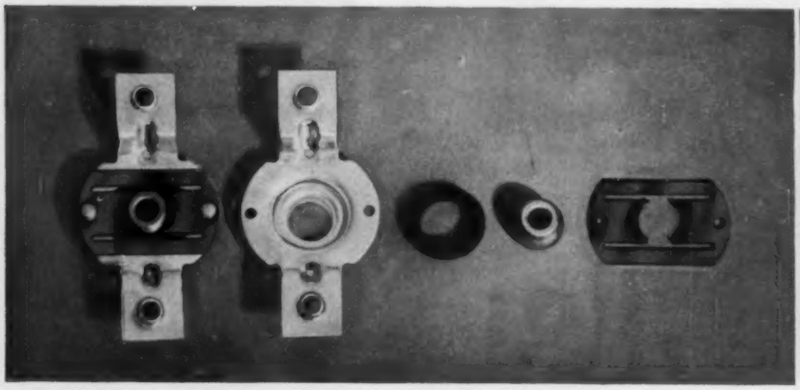
For further information circle No. 1299 on literature request card, page 48-D.

Vacuum Furnace

A new refractory-free, high-temperature vacuum furnace for critical heat treating has been announced by General Electric's Industrial Heating Dept. The new furnace operates at temperatures to 4200° F. and is designed for use in laboratories or for production work. Parts or material up to 10 in. in diameter by 10 in. high, weighing up to 50 lb., can be processed in the furnace. Heating space is 15 in. in diameter by 16 in. high. Double-wall furnace casing is of stainless steel with radiation shields surrounding the load to provide thermal insulation by reflecting heat back into the load. Inner shields closest to the load and which operate at highest temperatures are of tungsten. Those furthest from the work which operate at lower temperatures are of molybdenum. Last shield which supports the others is of stainless steel. Furnace cover is raised and lowered by screw-type mechanism

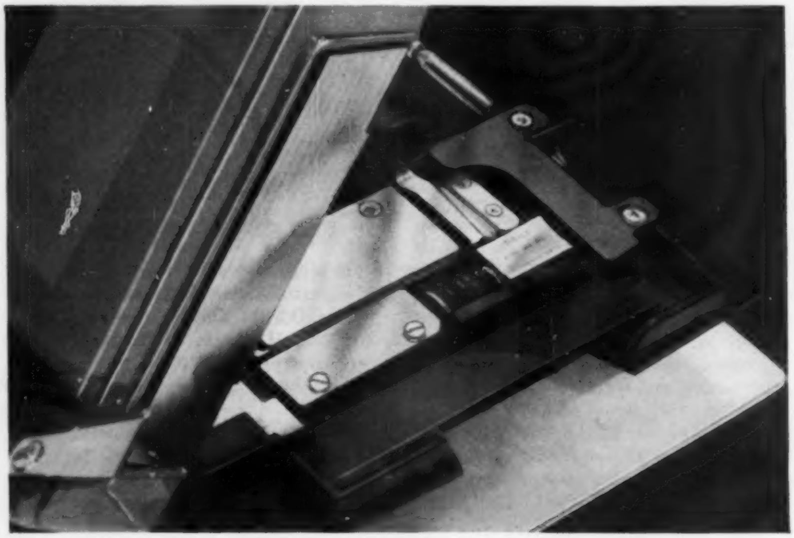
NEW BRONZE CAN CUT SPRING COSTS—

Superfine-grain phosphor bronze by Anaconda now handling many tough jobs, replacing costlier materials.



RETAINING CLIP for a bronze bearing in the Handy Hannah Hair Dryer was originally of spring steel. Rejections ran 20% in the stamping operation and another 20% at the assembly stage. The Handy Hannah Products Corp., Whitman, Mass., switched to Duraflex, Anaconda superfine-grain phosphor bronze, found it had not only the spring quality and fatigue resistance needed for the job—but also had superior formability which eliminated rejections.

SPRING CLIP takes a steady beating as it holds invoices in place in imprinting machines—used widely in handling charge accounts by retail stores and service stations. In the imprinter (right) made by the Farrington Mfg. Co., Needham Heights, Mass., this clip was originally of beryllium copper. Hearing about the superior fatigue life and endurance limit of Duraflex, Farrington consulted Anaconda technical specialists and decided to try it. Duraflex has been doing the job now for two years, stands up in service, saves $1.50 a pound in material cost.



Tests by an independent laboratory show that design stresses for Duraflex wire and flat springs can be from 33% to 50% higher than for those made from regular phosphor bronze—yet Duraflex costs no more than regular phosphor bronze. Get the test reports and revaluate all your components requiring spring properties. For copies of these reports or technical help in selecting the right alloy and temper, see your Anaconda representative. Or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5945

DURAFLEX®

SUPERFINE-GRAIN PHOSPHOR BRONZE

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ANACONDA®

Made by The American Brass Company

and top radiation shields move up and swing out for ease of loading and full access to heating chamber. Heating elements for the new furnace are ⅛-in. tungsten rods connected in parallel, and operate at less than 10 v. Vacuum system operates on a 6-in. oil-diffusion pump rated 900 cfm. at 0.01 micron and 1500 cfm. at 0.1 micron.
For further information circle No. 1300 on literature request card, page 48-D.

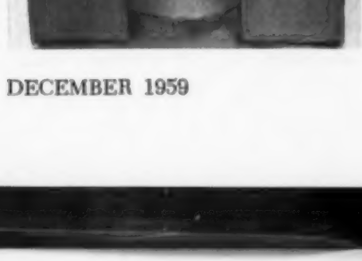
Microhardness Tester

A new semiautomatic microhardness tester has been announced by the Wilson Mechanical Instrument Div. It is recommended for testing of cutting tool carbide tips, watch springs, instrument pivots, surgical needles, electro-

plated surfaces, sheet metal and metallic constituents. It can be used in the production line and in the laboratory. It has a range of indentation loads from 25 to 1000 g. The instrument is equipped with a Bausch & Lomb microscope.
For further information circle No. 1301 on literature request card, page 48-D.

Vacuum Furnace

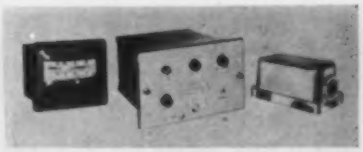
Materials Research Corp. has announced a new laboratory vacuum furnace that will perform melting, heat treating and brazing operations, and will grow single crystals by induction or resistance heating in high-vacuum or inert atmospheres. Depending on specimen size and convenience, these operations may be performed with the



furnace in either vertical or horizontal position. For standard heat treating and melting, an induction heating coil is used; for long-range heating or single crystal growing, a resistance unit with a maximum temperature of 3600° F. is installed. The vacuum chamber is a water-cooled unit 14 in. in diameter and 18 in. long, and can be equipped to reach vacuum of 10^{-5} mm. Hg.
For further information circle No. 1302 on literature request card, page 48-D.

Temperature Control

A new instrument utilizing infrared detection to measure and control the temperature of moving or stationary objects without physical contact has been announced by Radiation Electronics Co. The Thermodot radiation thermometer operates on the principal that an object emits thermal, or infrared, radiation as a function of its temperature; this thermal radiation from an object is received by the instrument, translated into a signal voltage, and amplified to a level sufficient to drive an indicator calibrated directly in temperature. Sensitivity is within 7° at 2000° F. The infrared sensing element is hermetically sealed within an optical head small enough to bolt onto any surface at a given working distance and aim in any direction at



the object to be measured. The lowest standard range is 180 to 400° F., and the highest 700 to 2000° F., although higher temperature ranges are available for special applications.
For further information circle No. 1303 on literature request card, page 48-D.

Spray Cleaner

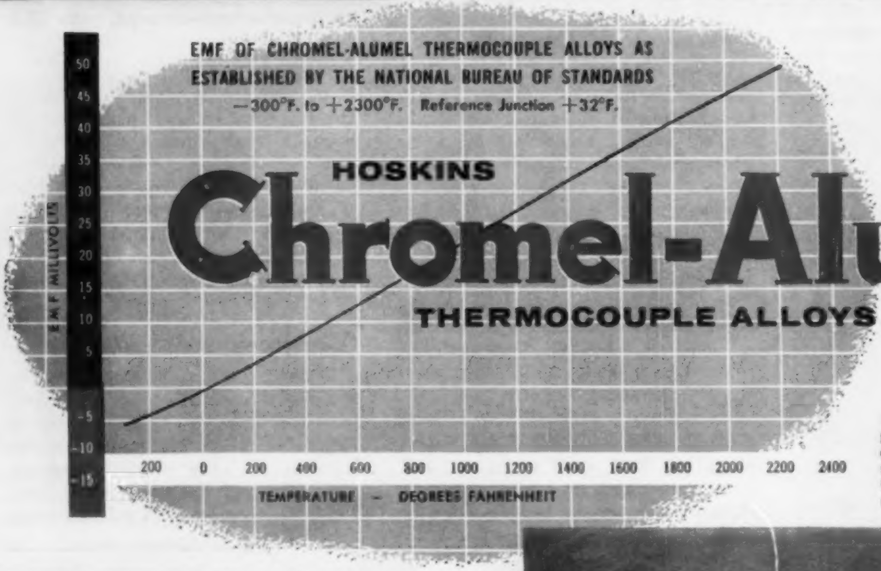
A low-foaming single or multiple-stage spray cleaner has been announced by Northwest Chemical Co. This new cleaner is designed for use on all ferrous and nonferrous metals except aluminum at 100 to 140° F. It removes drawing compounds, oils, and greases and inhibits rust.
For further information circle No. 1304 on literature request card, page 48-D.

Wiredrawing Machine

A new wiredrawing machine featuring ease of control and rapid braking has been announced by Nixdorff-Krein Mfg. Co. A 100-hp. motor, driving through an eddy current coupling, gives drawing speeds ranging from 200 to 650 ft. per min. A safety feature

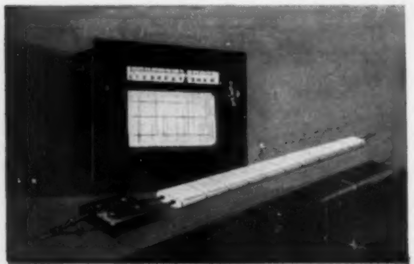
GUARANTEED MILLIVOLTAGE MATERIAL: The world's standard of accuracy for controlling the heat treatment of metals. Unconditionally guaranteed to register temperature-emf values within ±4°F. from −300° to +530°F.; and within ±¾ % from +531° to +2300°F.

SPECIFICATION 3-G-115: A guaranteed millivoltage material specially processed to close resistance limits for accurately measuring the high exhaust temperatures of jet aircraft engines.

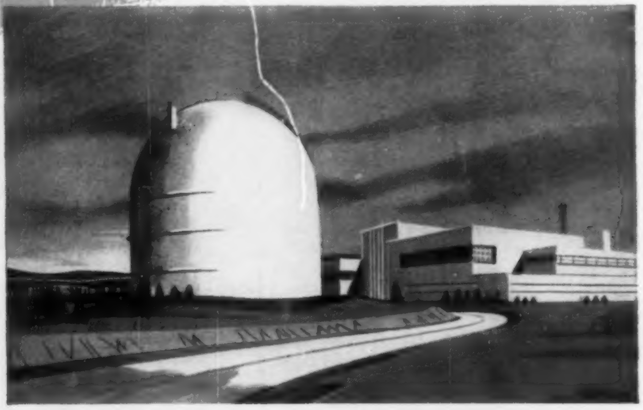


HOSKINS Chromel-Alumel* THERMOCOUPLE ALLOYS

SPECIFICATION 3-G-187: A special grade of material developed to meet critical control requirements of nuclear reactor applications. It is highly resistant to corrosion and has good stability of emf during long exposure at 500° to 1000°F.



CHROMEL-ALUMEL EXTENSION LEAD WIRE Widely used with Chromel-Alumel thermocouples to eliminate the cold-end errors often caused by so-called "compensating" leads of different compositions. Unconditionally guaranteed as to accuracy at temperatures up to 400°F.



SPECIFICATION 3-G-178: Specially processed close tolerance material widely used for precision research work. Accuracy of temperature measurement is guaranteed to be within ±5°F. over the operating range from 1000°F. to 2000°F.

*TRADE NAMES YOU CAN TRUST for accurate temperature measurement!

When you buy thermocouples, bear these facts in mind: Hoskins Chromel-Alumel are the only base metal alloys known which have been thoroughly proved in use at operating temperatures ranging from −300° to +2300°F. They are unconditionally guaranteed as to accuracy, extremely sensitive to temperature fluctuations, highly resistant to oxidation. What's more, when properly installed in suitable protection tubes, they give long-life service in any commercial furnace atmosphere. Catalog M-56-CA contains complete technical data—send for it today!

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prevents wire from whipping the floor as the coil end is drawn through the machine. The detachable capstan mount allows quick change from one coil diameter to another. In the picture above a coil of ⅜-in. wire is being drawn through the machine.
For further information circle No. 1305 on literature request card, page 48-D.

Vacuum Ionization Gage

An ionization gage that will resist rapid oxidization and burn-out if accidentally exposed to air has been announced by NRC Equipment Corp. The new gage will indicate vacuums from 1 micron to 10^{-7} mm. Hg with a sensitivity of 100 ma. per micron. It can be used in vacuum metallizing, vacuum melting and heat treating. A coated iridium filament that has superior resistance to burn-out at incandescent temperatures is used.
For further information circle No. 1306 on literature request card, page 48-D.

Mechanical Vacuum Pumps

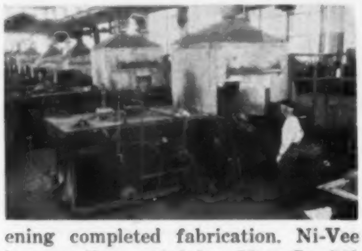
A new line of oil-sealed rotary mechanical vacuum pumps has been announced by Consolidated Vacuum Corp. They are available in single-stage and double-stage models. The rated capacities of the pumps range from 7 to 106 cfm. Noise has been reduced by an air-valve suppression

port and by reduction of vibration through static and dynamic balance of the piston-drive assembly. The motor is standard 220 or 440 v., 3 phase, air

cooled. Ultimate pressure is 2×10^{-3} mm. Hg or lower with the single-stage pumps and 2×10^{-5} mm. Hg or lower with the double-stage pumps.
For further information circle No. 1307 on literature request card, page 48-D.

Continuous-Cast Bronze

American Smelting & Refining Co. has announced the production of 20-ft. bronze stems, each 4½ in. in diameter and weighing 1300 lb. The stems are used unsupported to hold sluice gates. Each stem has to bear a torque load of 2500 ft-lb. and an axial load of 56,000 lb. The rods were cast and cut to 20-ft. lengths. (See the illustration below.) Sample wafers from the ends of each rod were checked for conformity to chemical and metallurgical specifications and response to heat treatment. The rods were heat treated at 1400° F. for 8 hr., and quenched in oil. The stems were straightened and re-heated to 600° F. for about 16 hr. and again the sample wafers were checked for hardening. The rods were then slowly air cooled. A final straightening completed fabrication. Ni-Vee bronze alloy containing 88% Cu, 5% Sn, 5% Ni, 2% Zn and 0.01% max Pb was used. After heat treatment the stems had a yield strength of 69,000 psi., tensile strength from 75,000 to 90,000 psi., elongation of 6 to 9% and and average Brinell hardness of 250.



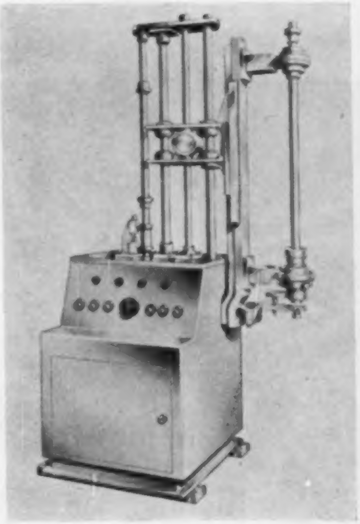
For further information circle No. 1308 on literature request card, page 48-D.

Ductile Chromium Metal

Successful extrusion of pure chromium metal tubing has been announced by Union Carbide Metals Co. The extrusions were made of laboratory-grade chromium powder that was cold compacted into a mild steel container, heated, placed in a 1000-ton press and extruded over a mandrel. A variety of tube sizes were made during the first runs of the experiment including 1, 1.2 and 1.4-in. O.D. with 0.06, 0.07 and 0.10-in. wall thicknesses.
For further information circle No. 1309 on literature request card, page 48-D.

Scanning Machine

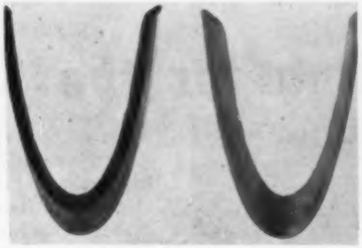
A new induction heater for production of pure metals and semiconductor materials has been announced by Induction Heating Corp. The new vertical scanner can be used in laboratory or production operations. After a narrow molten zone is established, the scanning machine traverses along the length of the vertically supported impure bar. The complete molten zone through the bar cross section is maintained by electromagnetic forces, surface tension and hydrostatic pressure. The machine will process bars up to 1.250 in. in diameter and 24 in. in length. Scanning speed ranges from 0 to 12 in. per hr. Return speed varies from 40 to 800 in. per hr.



For further information circle No. 1310 on literature request card, page 48-D.

Electroforming

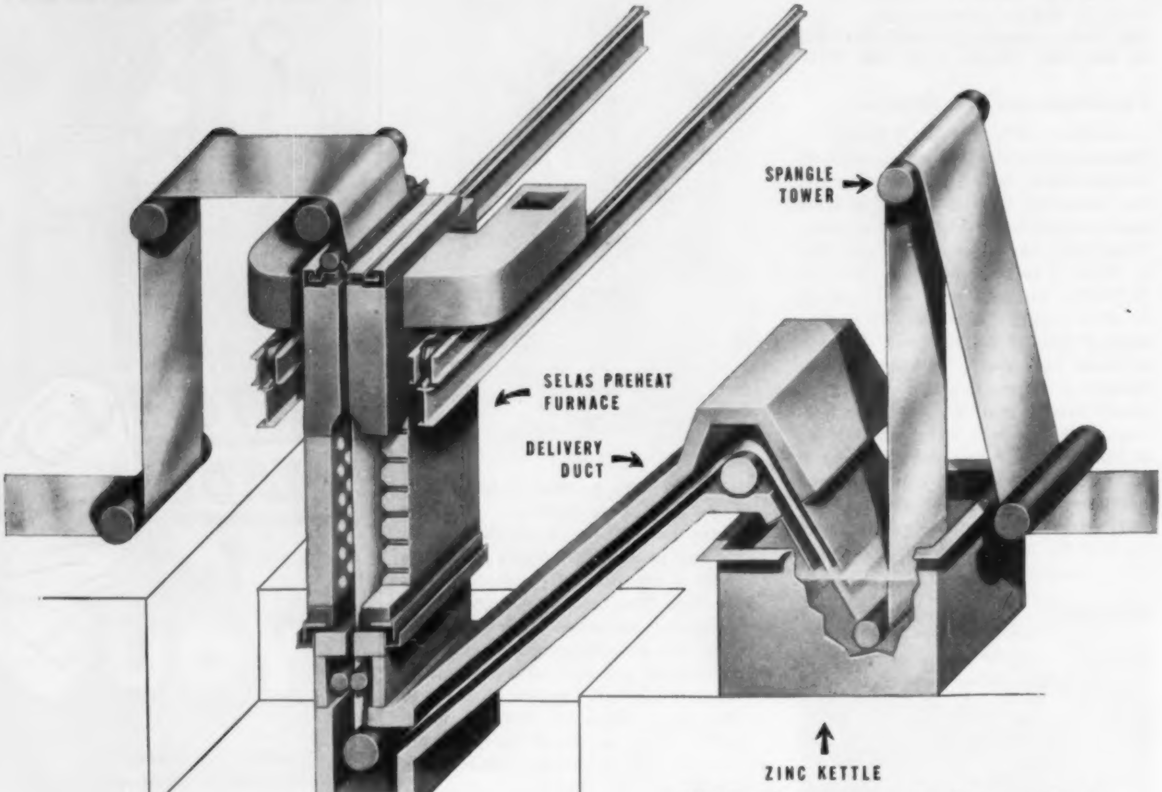
Electroformed aircraft parts have been announced by Electroform Corp. The process involves the electrochemical deposition of metal and is suitable for the manufacture of complex shapes where close dimensional control is necessary. A good finish is obtained without further machining.



For further information circle No. 1311 on literature request card, page 48-D.

Vacuum Induction Furnace

A 5000-lb. high-vacuum induction furnace has been erected at the Metals Div. of Kelsey-Hayes Co. The entire melting chamber tilts to pour. During pouring, the molten metal



GALVANIZING STEEL STRIP . . New Selas approach to continuous galvanizing steps up production of quality product without increasing floor space occupied by original installation. Compact Selas vertical furnace quickly preheats strip to galvanizing temperature . . eliminates need for fluxing . . fits into line, replacing fluxing equipment. External firing of zinc kettle is minimized because evenly heated strip imparts heat to zinc bath . . achieving (1) longer kettle life, (2) less zinc consumption, (3) reduced dross formation and (4) uniform coating. Unusual safety feature provides fast, automatic withdrawal of furnace from strip in case of line stoppage.

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Throughout the steel industry–in mills and metalworking plants–Selas Gradiation heat processing is successfully used in many operations. The versatility and adaptability of the Gradiation principle are demonstrated by the diversity of applications shown in the installation photographs on facing page.

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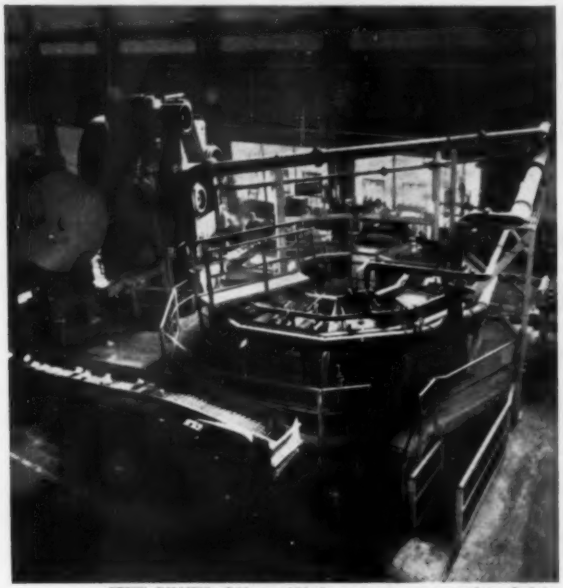
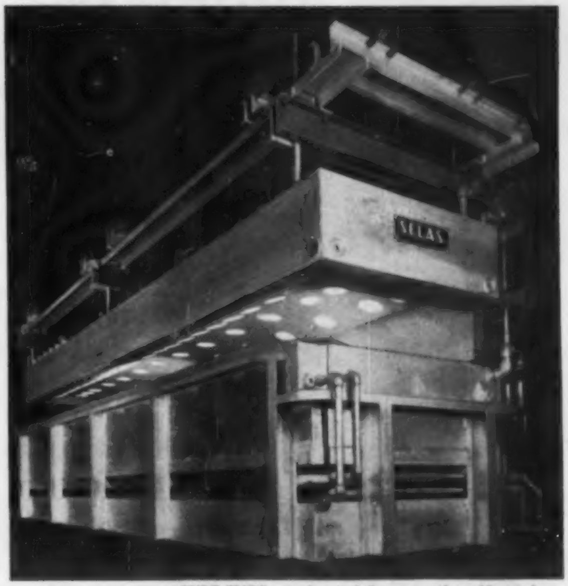
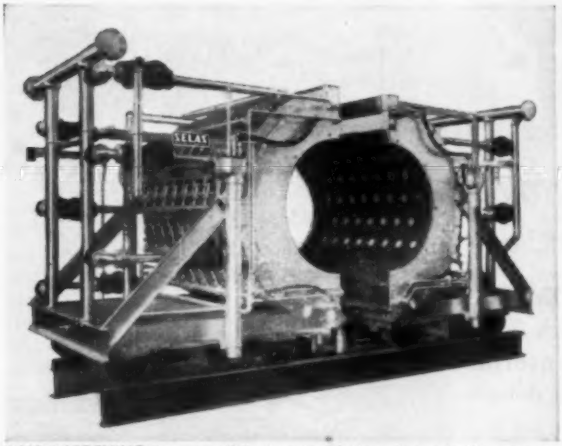
is your reward



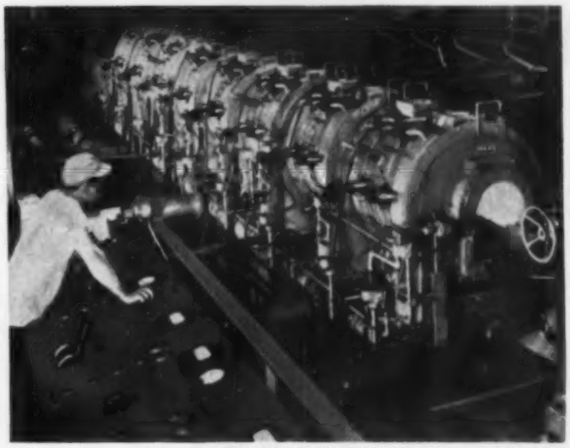
STEEL BILLETS, 3½ to 4¼ in. square cross-section, 3.4 to 10.8 in. long, are heated for hot working in this Gradiation rotary hearth. Compact furnace occupies 60% less floor space than required by conventional heat-and-soak equipment to achieve production rate of 11,000 lb per hr. Scale loss is 85% less. Entire heating cycle—as well as charge, discharge, transfer and press loading—is automated and synchronized with press operations.



TUBE-ENDS are heated for upsetting (for subsequent threading) in specially-designed Selas slot-type furnaces. As each tube-end is fast heated to upsetting temperature, the tubing automatically moves down the handling table to the upsetting machine. The direct-fired Duradiant® gas burners are patterned to assure temperature uniformity within a controlled section of each tube-end.



ROLL HARDENING is accomplished up to 12 times faster in this unique direct-fired Selas split furnace. Patterned Gradiation heating . . coupled with the ability to rotate rolls during heating and quenching cycles . . assures attainment of a controlled pattern of hardenability. Heat-up time is so rapid that harmful scale is eliminated. Even-heat distribution prevents formation of soft spots. Protection of roll shoulders leaves them unaffected by heat processing of roll barrel. Rolls up to 60 in. in diameter and a wide range of barrel lengths can be hardened.



SEAMLESS TUBING is heated for final sizing in this Selas eight-barrel continuous furnace line. Three zones of automatic control assure that the heavy-walled tubing . . up to 16 in. O.D. and 3 in. wall thickness . . is brought precisely to predetermined temperature, throughout each length of tubing . . consistently uniform from tube to tube.

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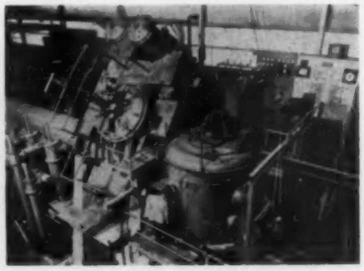

passes through a tundish in the pouring chamber and into the mold chamber. The complete process takes place under vacuum, which during pouring, is as low as one micron. The furnace has dual-frequency power—high-frequency power for heating and multiphase low-frequency power for mixing.
For further information circle No. 1312 on literature request card, page 48-D.

Metal Cleaning

Heatbath Corp. has announced a new solvent emulsion detergent that cleans and protects the metal in one operation. Normally, Pen Sol No. 2 is used at 1 to 2% with water at room temperature. It may be employed as a soak cleaner, or in single or multiple stage washers. It may be used hot.
For further information circle No. 1313 on literature request card, page 48-D.

Torsion Spring Tester

A new fixture for rapid testing of torsion springs featuring interchangeable arbors and 360° protractor has been announced by the P. A. Sturtevant Co. This tester uses a torque wrench as a sensing element, allowing various ranges from inch-grams up to 100 in-lb.
For further information circle No. 1314 on literature request card, page 48-D.

Stainless Tubing

Allegheny Ludlum Steel Corp. has announced a new method of fabricating AM-350 stainless steel tubing. Separate elbows and joints are eliminated because it can be bent to the desired degree. Flanges are made

integral with the tubing. Tubing is formed in a dead-soft annealed condition. After the metal has been fabricated, it is process annealed and then treated at subzero temperatures to maximum strength and hardness.
For further information circle No. 1315 on literature request card, page 48-D.


THE BEAUTY OF utility
CLEAN
BRIGHT
ENDURING
STURDY
The Stainless Steel products illustrated are made by STEELEX Corporation, Williamsport, Pa.
in Superior Stainless
STRIP STEEL
SERVICE-ABLE Superior Stainless performs handsomely in these functional utensils—always bright, easy to clean, with extra strength for extra years of use. • Superior Stainless delivers handsome performance in fabrication, too . . . handles *right* because of superior quality control at every stage of manufacture. • We have much to offer in technical assistance. Write us on your stainless applications.
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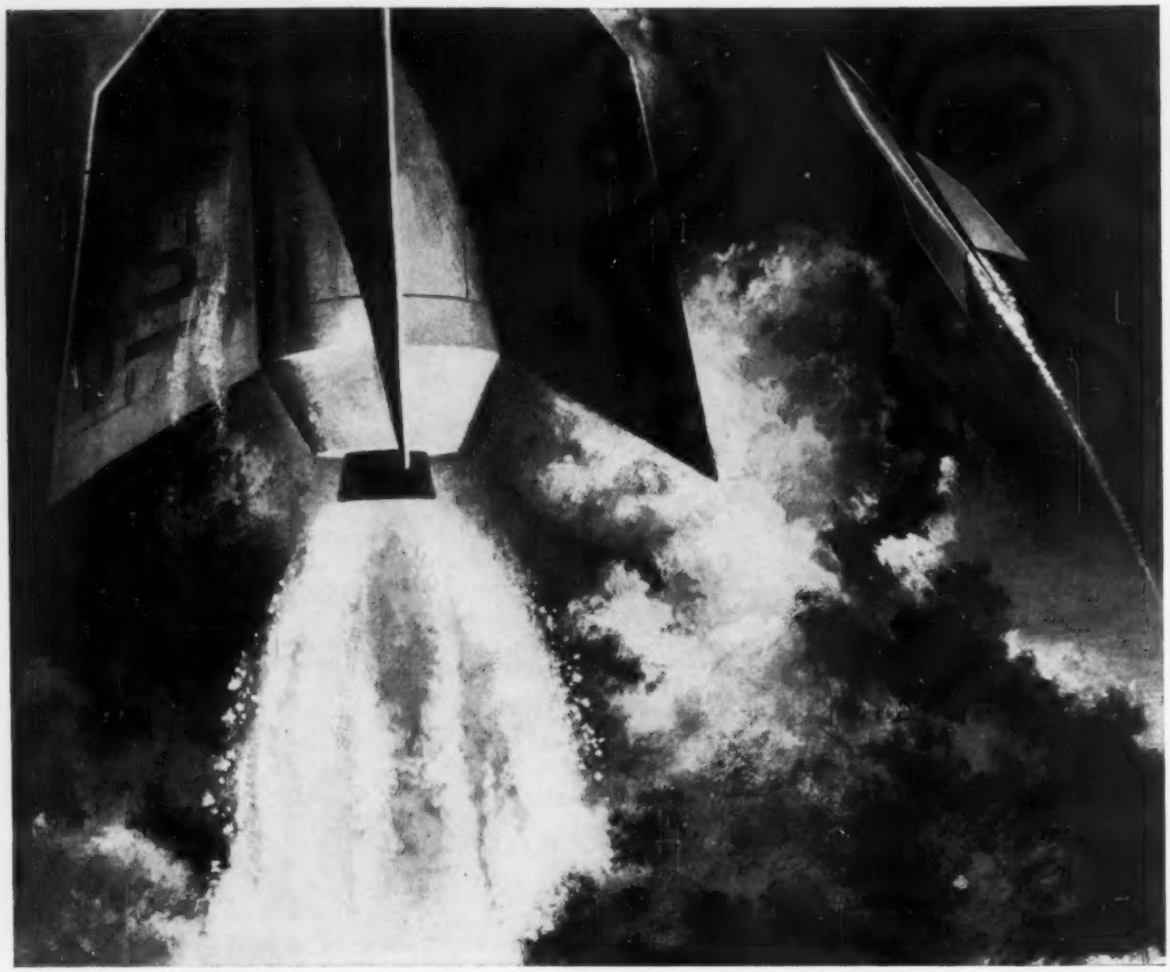

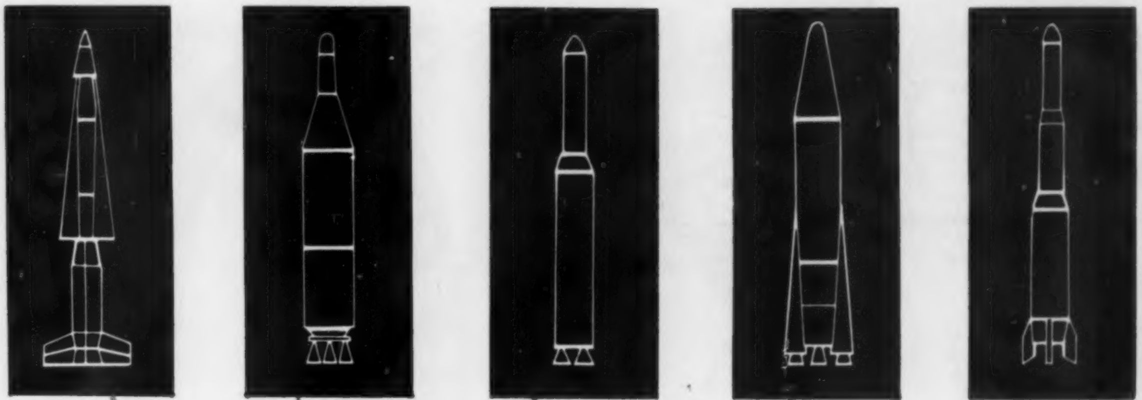

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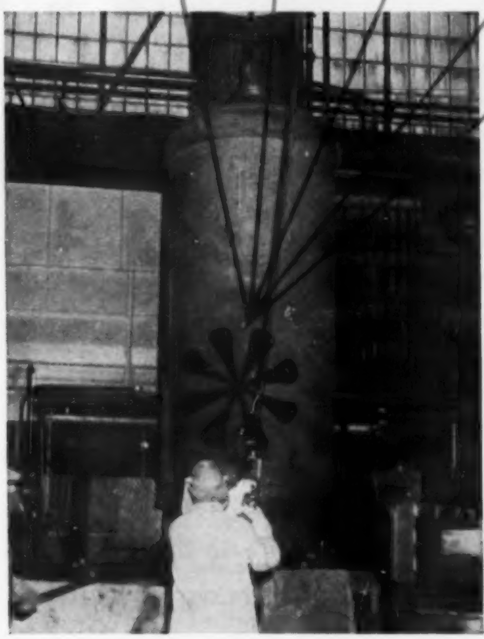

In four of the largest salt bath quenching operations in the U. S., Houghton Mar-Temp Salts are used to quench vital components and flight chambers of a wide variety of missiles and rockets.

The precision quenching possible with Houghton Mar-Temp Salts prevents distortion and cracking, yet insures the strength and hardening accuracy necessary for precise performance and reliability. Missile metallurgists also prefer Mar-Temp quenching for greater cleanliness and to eliminate safety equipment needed in oil quenching.

Houghton's care in compounding salts and Houghton heat treating "Know-How" were major factors in the selection of Mar-Temp Salts for such important defense projects. You can get the same expert help and high-quality materials for your own heat treating processes by a call or letter to E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.

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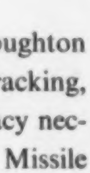

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SPECIFICATIONS

Weight	40 pounds
Capacity . . .	up to 30 curies of Iridium 192
Working Distance. . . .	50 feet from operator to exposed source.
Machine . . .	lead shielded, stores source when not in use.
Uses	¼ inch to 3 inches of steel (or equivalent)

The President of Universal Technical Testing Laboratories Inc., Havertown, Pa., praises the safety, portability, economy and versatility of Nuclear Systems' Model 40 Iriditron radiography machine.

Said Mr. William J. Duffy, "It weighs only 40 pounds and one man can put it in the trunk of a car, take it to the job and make quick and safe exposures. This portability saves us time and money.

"Using Iridium 192 as the source, this Model 40 machine is equivalent to a 440 KVP X-ray machine."

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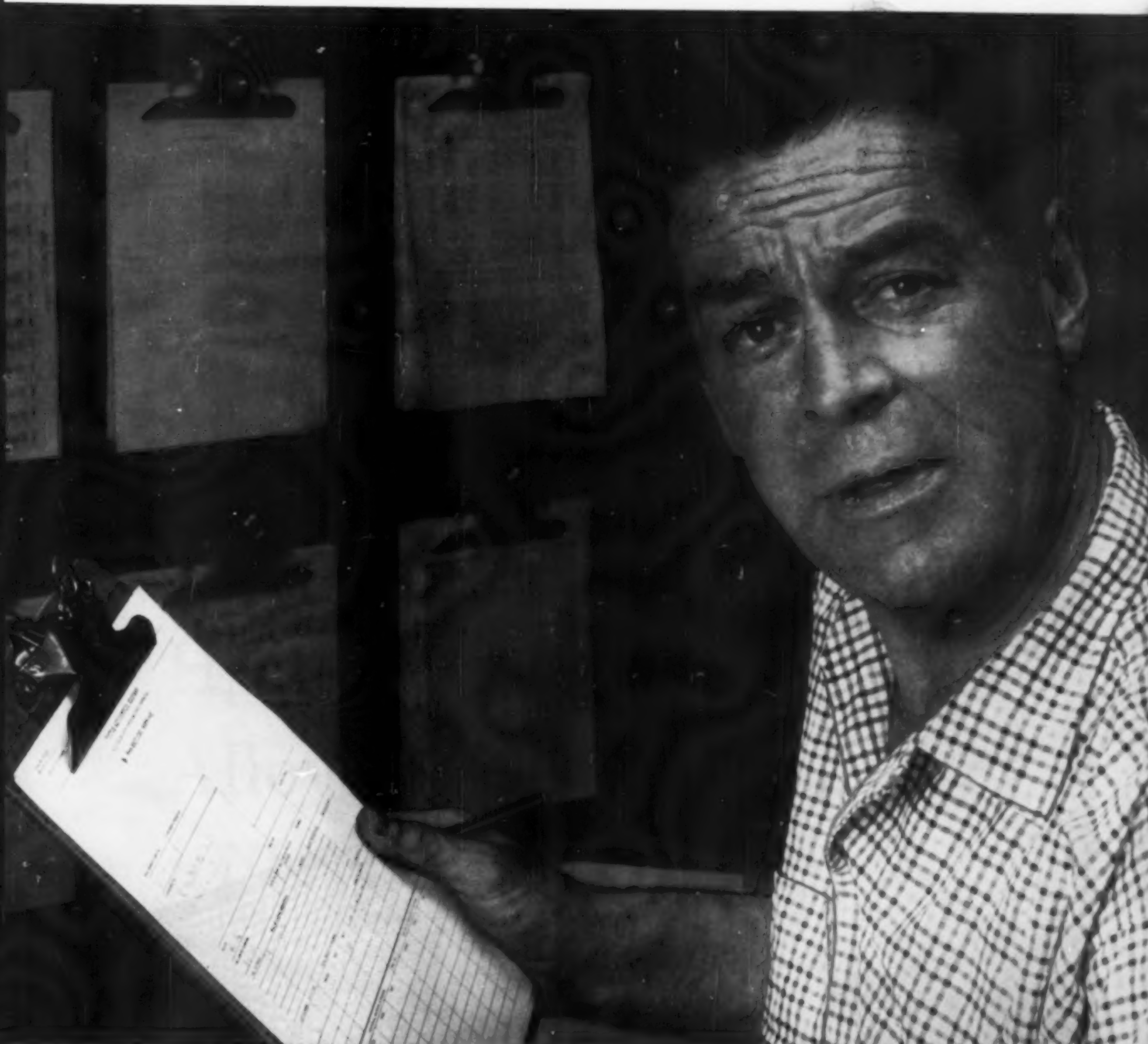
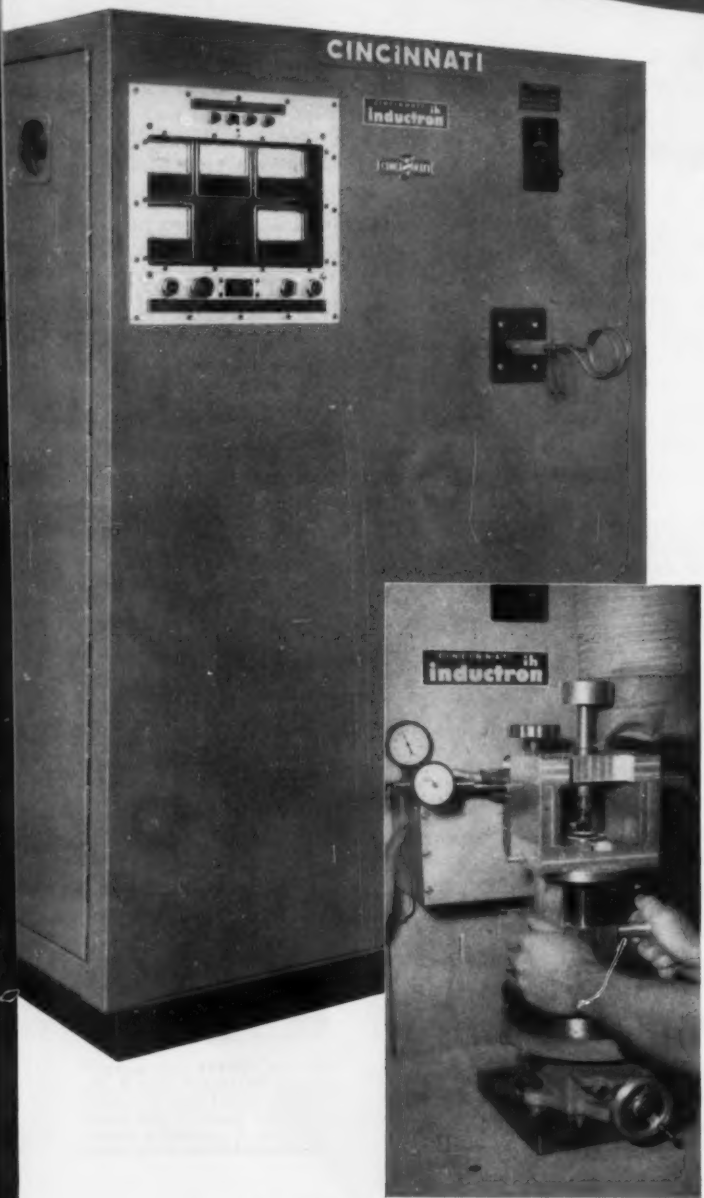



FOR THE METAL PART

with just a KISS of 1000 kc's

CINCINNATI inductron® precision-brazes Statham Pressure Transducers



Photos above show Cincinnati Inductron induction heating machine and close-up of fixture used to braze 150 different sizes and styles of pressure transducers. Hose over fixture exhausts heat. One type of completely assembled Statham Pressure Transducer is shown, above, actual size.

Statham Instruments, Inc., Los Angeles, required a brazing operation before the final assembly of their extraordinarily accurate pressure transducers. These instruments record pressures ranging from fractions to thousands of psi. Among other sensitive components, the coils in these instruments are wound from wire so fine that it floats in air. To braze these transducers, the heat must be precisely located and applied . . . or a nearly complete, accurately adjusted instrument will be destroyed.

Because of its precise control of high frequency output (up to approx. 1200 kc) a Cincinnati 15 KW Inductron was the economical solution to this assembly problem. Brazing three joints is typical of the work accomplished. Using a calibrated fixture on an adjustable table for exact work positioning, the joints are quickly brought up to brazing temperature. The heat cycle for some transducers is but 0.2 second—just a kiss of 1000 kc's. With the Inductron's variable output RF transformer—rotating a dial varies the heating characteristics of the coil—only 25 different coil forms are needed to braze 150 instrument sizes and styles.

For your heat processing work, look to the Cincinnati Inductron for lowest cost induction heating . . . and to the Cincinnati Flamatic for lowest cost flame heating. Call in a Meta-Dynamics Division field engineer for full details.

inductron
flamatic
hardening machines

META-DYNAMICS DIVISION
Machines for Metal Forming and Heat Treating

THE CINCINNATI MILLING MACHINE CO.
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APPLICATION and EQUIPMENT new literature

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Catalog of rubberized abrasives, uses, advantages. Price list. *Cratex Mfg. Co.*

1317. Air-Hardening Steel
8-page booklet gives composition, properties, elevated-temperature properties and heat treatment. *Latrobe Steel*

1318. Alloy Steel Castings
Specifications for T-loy 34 and T-loy 42. Heat treatment and characteristics. *Unitcast Corp.*

1319. Alloy Steel
40-page book on applications of heat treated, special alloy steel. *Jones & Laughlin*

1320. Alloy Steels
Article on use of chromium-molybdenum-vanadium steel for service at elevated temperatures. Chemical composition, mechanical properties. Vancoram Review, V. 13, No. 1. *Vanadium Corp.*

1321. Aluminum
Brochure describes production equipment, products, research facilities of aluminum plant. *Anaconda Aluminum*

1322. Aluminum
8-page bulletin on aluminum casting alloys. Properties; selection of casting method: pig, ingot and billet compositions. *Metals Div., Olin Mathieson Chemical*

1323. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1324. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

1325. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

1326. Aluminum-Iron Alloys
Technical Data Bulletin Ind-18, on aluminum-iron alloys for applications requiring high quality, soft magnetic materials. *General Plate Div., Metals & Controls Corp.*

1327. Aluminum Strip
20-page booklet on how it is made, sizes and weights of coils. Technical data on aluminum alloys used. *Scovill*

1328. Aluminum Tubing
New 48-page book on aluminum tubing. Alloys, properties, selection, applications. *Revere Copper & Brass Co.*

1329. Ammonia
18-page booklet on ammonia cylinder installations for metal treating. Physical and chemical properties. *Armour*

1330. Analytical Instruments
Newsletter No. 5 has article on new vacuum scanning spectrometer. *Jarrell-Ash*

1331. Atmosphere Controls
6-page bulletin SC-181 on automatic dew point recording and controlling systems. *Surface Combustion Corp.*

1332. Atmosphere Furnace
Bulletin HD-1 on batch-type controlled atmosphere furnace. Specifications, atmosphere circulation. *Dow Furnace Co.*

1333. Atmosphere Furnace
12-page bulletin 1054 on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

1334. Barrel Finishing
36-page booklet on complete line of abrasive mediums, compounds, and equipment for all tumbling operations. *Electro Minerals Div., Carborundum Co.*

1335. Bearing Plates
New brochure on stainless-clad steel bridge bearing plates describes testing and performance of steels and plates. *Lukens Steel Co.*

1336. Beryllium
16-page Reprint 34 on fabrication of beryllium. Five pages of property data. *Brush Beryllium Corp.*

1337. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1338. Blackening Process
4-page brochure on new activated material for black oxide processing. *Mitchell-Bradford Chemical Co.*

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Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

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8 page booklet on composition, structure, corrosion resistance, welding and mechanical properties of 1% boron stainless steel. *Superior Steel*

1341. Brazing Alloys
Data on brazing stainless alloys. *Wall Colmonoy*

1342. Brazing
8-page reprint on production brazing illustrates items produced and how they are made. *Selas Corp.*

1343. Carbon Brick
Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

1344. Carbon Potential Controller
Information sheet on instrument for use with endothermic gas generators and controlled atmosphere furnaces. *Rolock*

1345. Carbon Steel Tubing
Data card 142B on properties of pressure tubing: fabrication operations used. *Tubular Products Div., Babcock & Wilcox Co.*

1346. Carburizing
Bulletins A-1 and A-2 on liquid carburizing. Equipment, bath make-up and maintenance, cyanide analysis. *Park Chemical*

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Data on chromium plate that can withstand fabrication. *American Nickeloid Co.*

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34-page booklet traces story of copper from discovery to present applications. *Copper & Brass Research Assoc.*

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Data sheet on beryllium oxide crucibles for melting high-purity and reactive metals. Specifications and sizes. *Beryllium Corp.*

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Folder describing nine types of cutting oils for varied applications. *Gulf Oil Corp.*

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Data on ductile iron plate and properties. *Lindgren Foundry Co.*

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Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

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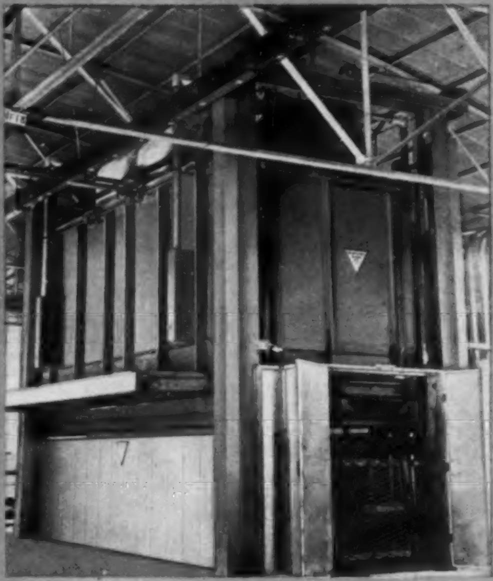
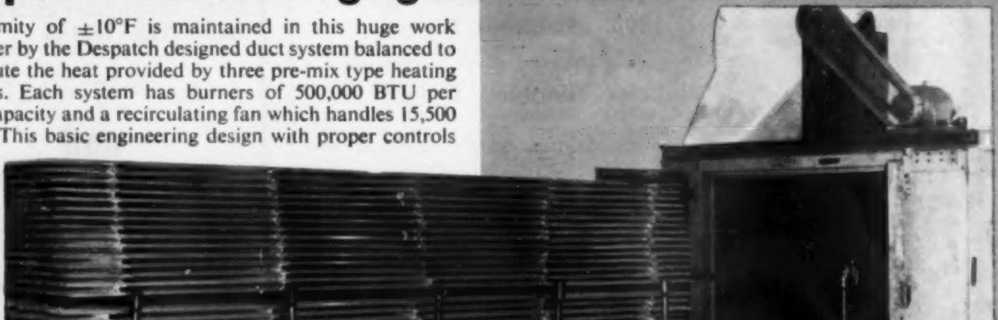


Where best mechanical properties are required from A356 aluminum castings, heat treatment should follow definite time at temperature programs. Careful adherence to quenching time and quench temperatures will alter tensile strength and elongation. Heat treating furnaces by Despatch achieve temperature uniformity in the work chamber to minimum tolerances. Quenching time and quench temperature can be controlled to fit the metallurgical program required. Despatch engineers have built aluminum furnaces to the requirements of major aluminum producers and fabricators through all stages of aluminum industrial development.

Despatch developed furnace features now make possible the proper heat treatment of A356 al. alloys. Check Despatch for the correct furnace for all of your aluminum and aluminum alloy heat treating requirements.

Despatch aluminum aging oven treats 44 ft. extrusions

Uniformity of $\pm 10°F$ is maintained in this huge work chamber by the Despatch designed duct system balanced to distribute the heat provided by three pre-mix type heating systems. Each system has burners of 500,000 BTU per hour capacity and a recirculating fan which handles 15,500 CFM. This basic engineering design with proper controls maintain the necessary heat uniformity to age these 44 ft. extrusions to specification in minimum time.



For any al-mg alloy heat treating requirements we invite your inquiry. A Despatch engineer will give prompt service to your particular heat treatment problem and recommend a furnace design for the job.

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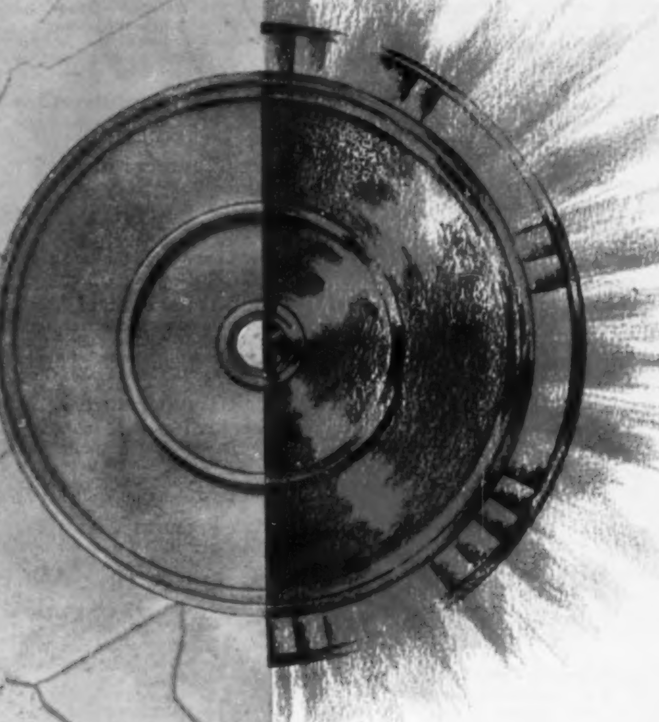
1-page flier describes basic hot topping



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can be accomplished with WYMAN-GORDON forgings. Optimum metallurgical practice and quality control provide higher property levels and reduced variation within and between forgings to permit generally the following GUARANTEED MINIMUM mechanical properties for contoured wheels and discs up to 50 inches in diameter.

RENÉ 41*

Typical Mechanical Properties

TENSILE PROPERTIES:	Room Temp.	1400° F
Ultimate Strength, psi	200,000	145,000
.2% Yield Strength, psi	150,000	125,000
.02% Yield Strength, psi	135,000	110,000
Elongation (% in 2")	15	18
Reduction in Area, %	18	20

STRESS RUPTURE:	Combination Smooth and Notch Bar	Smooth Bar
Temperature, ° F	1350	1650
Stress, psi	85,000	25,000
Life, Hours	100	50
Elongation, %	12	12
Reduction in Area, %	14	14

Guaranteed Minimum Mechanical Properties

TENSILE PROPERTIES:	Room Temp.	1400° F
Ultimate Strength, psi	180,000	135,000
.2% Yield Strength, psi	132,000	115,000
.02% Yield Strength, psi	120,000	100,000
Elongation (% in 2")	12	13
Reduction in Area, %	14	18

STRESS RUPTURE:	Combination Smooth and Notch Bar	Smooth Bar
Temperature, ° F	1350	1650
Stress, psi	85,000	25,000
Life, Hours	40	25
Elongation, %	8	10
Reduction in Area, %	10	12

*RENÉ 41, GENERAL ELECTRIC COMPANY

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Forgings of other Nickel Base Alloys with superior guaranteed properties are also available. Wyman-Gordon is prepared to serve you at the design, engineering and purchasing stages of your developments.

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unit for use on vacuum induction melting furnaces. *Zak Machine Works*

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12-page catalog on finishing systems, cleaning, pickling, rustproofing equipment, ovens, conveying equipment. *R. C. Mahon Co.*

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32-page catalog on Heroult electric furnaces. Design, types, sizes, capacities, ratings. *American Bridge*

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56-page Catalog No. 32 gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric*

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8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

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Bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. *Young Bros.*

1462. Ovens
Bulletin 4-257 on gas, oil and electric ovens. Load-carrying-door, electric-drawer and walk-in type ovens. *Grieve-Hendry*

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Data on forging, machining and finishing facilities for parts production. *H. K. Porter, Forge & Fittings Div.*

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4-page Bulletin 1271 on small self-balancing electronic potentiometers and bridges. *Bristol Co.*

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Folder on how powdered metal parts can replace machined parts. *Norwalk Powdered Metals, Inc.*

1470. Powder Metallurgy
16-page booklet on advantages and disadvantages of process, design data, materials used. *Reese Metal Products*

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8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1472. Protecting Tubes
Data folder on thermocouple protecting tubes. Alloys used and prices for formed and drilled tubes. *Claud S. Gordon Co.*

(*Continued on page 48-A*)

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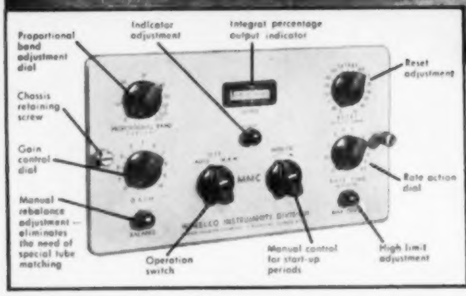

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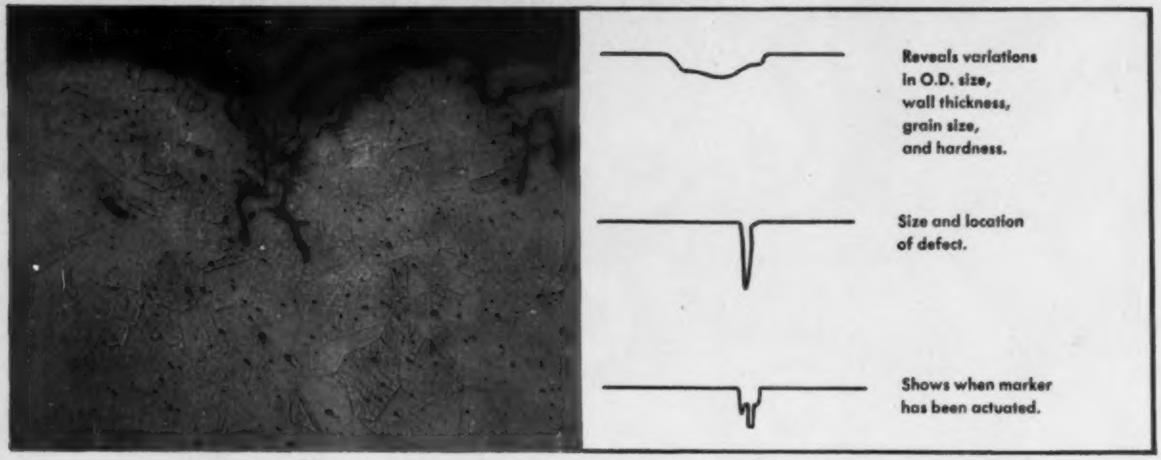

This flaw is .004 square inches in area
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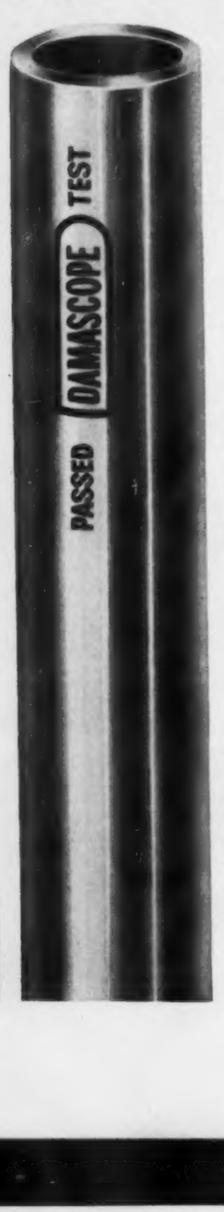

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20	0.035	0.005	0.0020
18	0.049	0.006	0.0024
17	0.058	0.007	0.0028
16	0.065	0.008	0.0032
15	0.072	0.009	0.0036
14	0.083	0.010	0.0040

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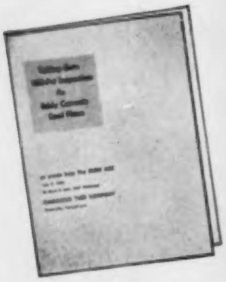

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CASE HISTORY

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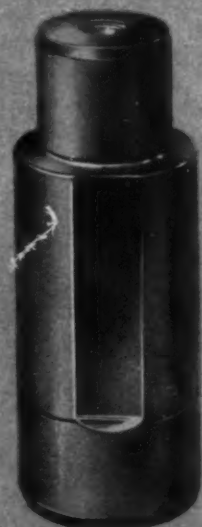
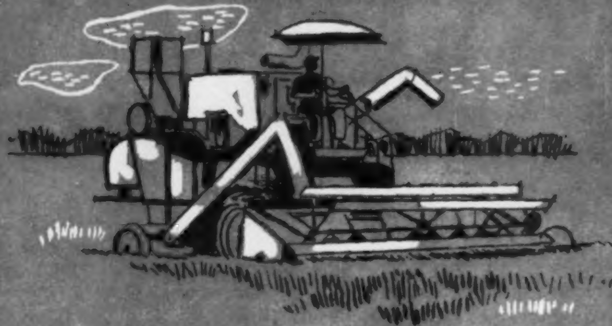
This heavy duty planetary pinion shaft, made as a screw part from tough "600" series bearing alloy, was the answer to a continuing wear problem encountered in the driving mechanism of heavy-duty farm equipment and big trucks. The part is machine produced to exacting tolerances and all necessary finishing operations are done by Mueller Brass Co. so the pinion shaft is ready for installation when received. Since "600" alloy parts have been installed, no operating failures have been reported and the shafts have proved far superior to the material formerly used.





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CASE HISTORY

MUELLER BRASS CO. 600 ALLOY forgings used in aviation air compressors

Analyzing the job requirements of Walter Kidde & Company, Inc., for a main driving cam component to be installed in a reciprocating type of aircraft air compressor, Mueller Brass Co. Methods Analysis Engineers decided on a forging fabricated from "600" alloy as the most practical method of production. Since the cam forms the prime component of the driving mechanism, it must have good bearing wear surfaces and because the compressors are used in the aviation industry, the cams must be completely dependable. The close grained, strong forging that resists combination compressive and tensile stresses was the answer.

A typical compressor takes in ambient air and compresses it to 3000 psi or higher. This high pressure air is stored in metal or fiberglas containers until needed for actuation of pneumatic system components such as solenoid control valves, brake valves, manual control valves or actuators. These and other pneumatic units retract the entrance door, operate landing gear, wheel brakes, nose wheel steering systems, propeller brakes or perform other functions.

Aircraft in which Kidde compressors are installed include the Boeing 707, the Douglas DC-8, the Lockheed Electra, the Fairchild F-27 and various military aircraft.

Mueller Brass Co. produces press, hammer or cored forgings of any practical shape from a few ounces to 150 lbs. in brass, bronze, aluminum and magnesium in 27 standard, as well as special, alloys.

Aircraft air compressor equipped with hydraulic drive delivers air compressed to 3000 psi at the rate of 6 cfm.

This yoke forging is lightweight, yet strong; has excellent bearing wear surfaces.

Forging is part of the main cam, the prime component of a modified Scotch-type yoke, which is the piston driving mechanism in the air compressor.

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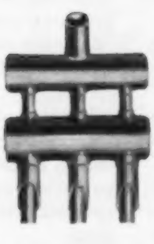

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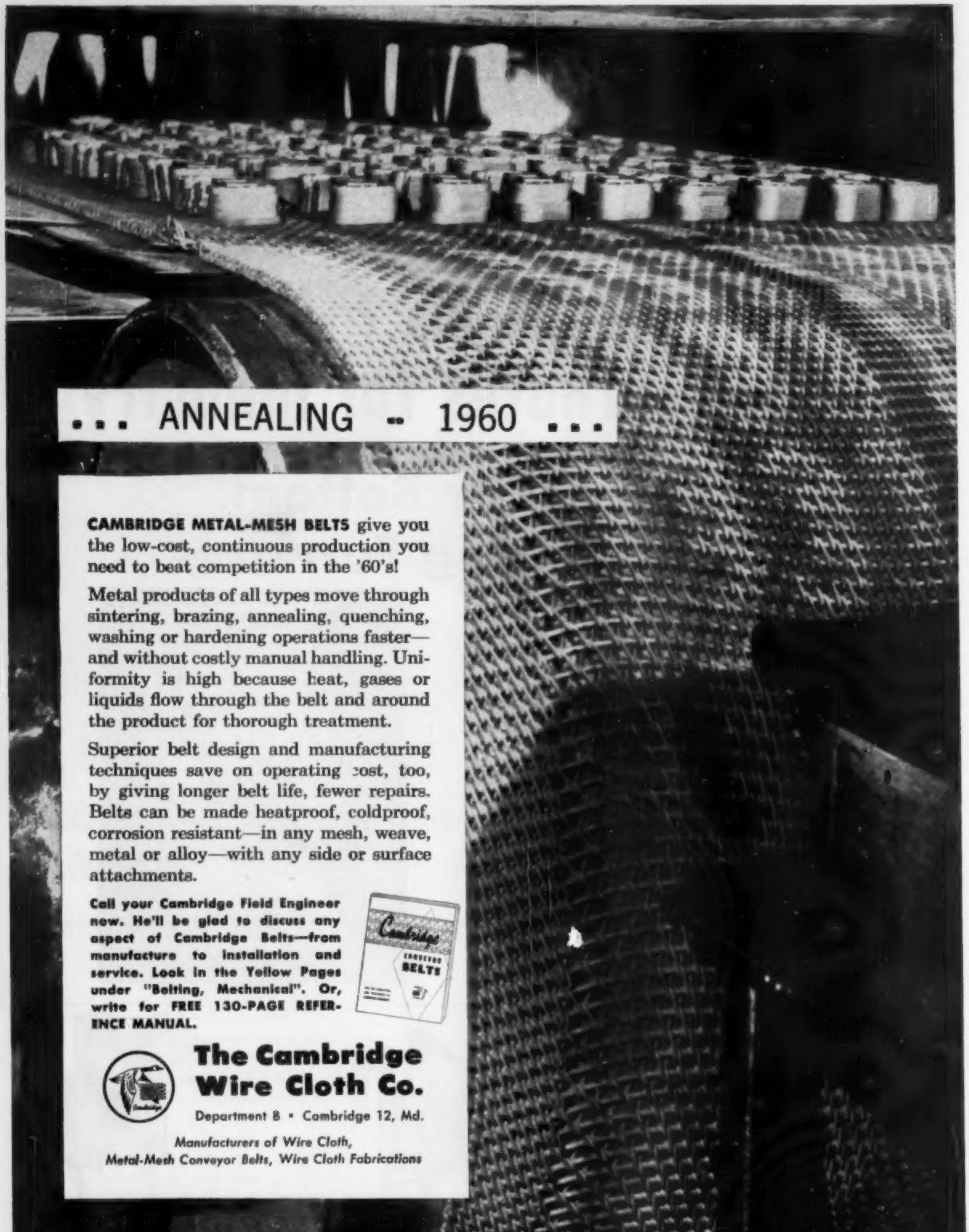
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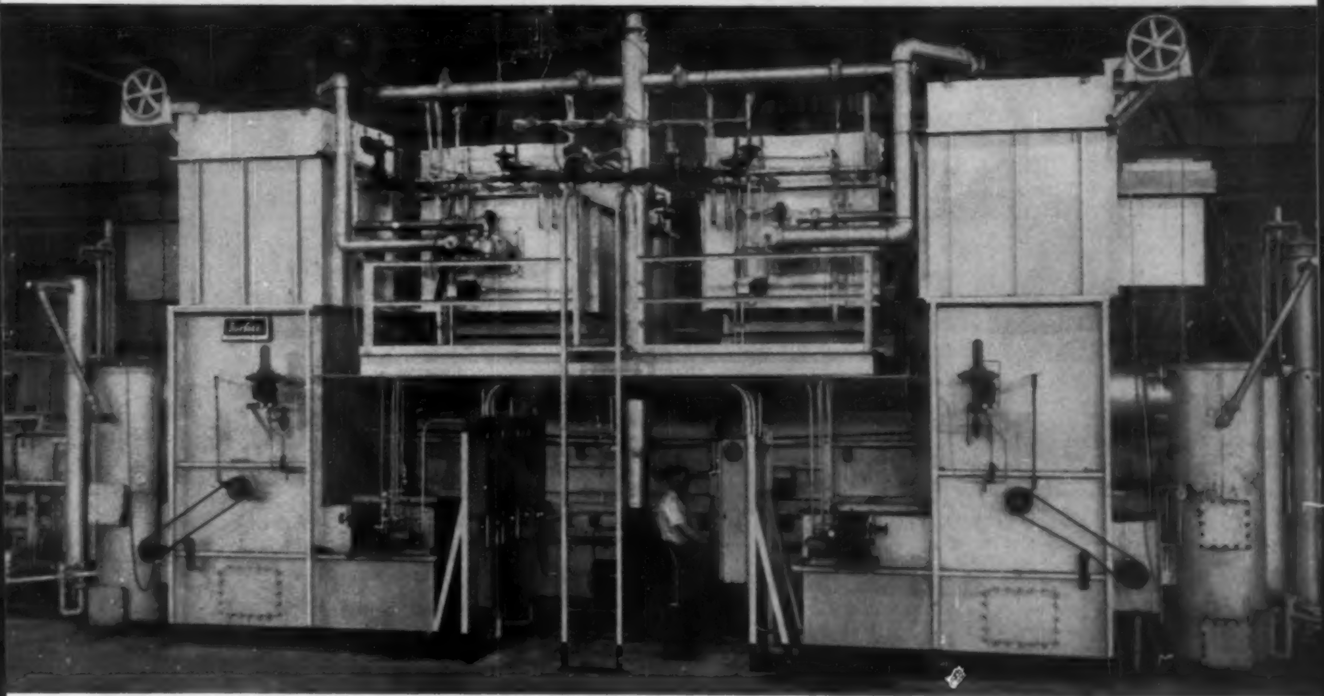

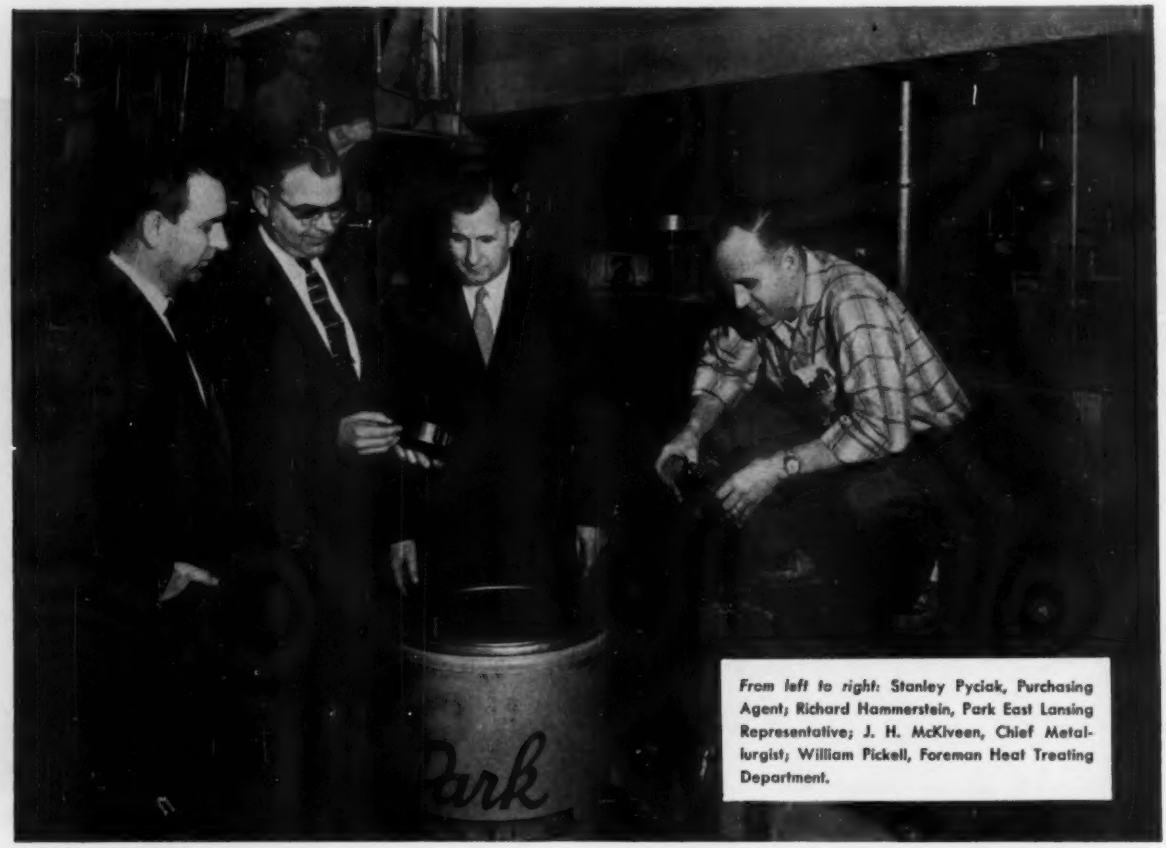

From left to right: Stanley Pyciak, Purchasing Agent; Richard Hammerstein, Park East Lansing Representative; J. H. McKlveen, Chief Metallurgist; William Pickell, Foreman Heat Treating Department.

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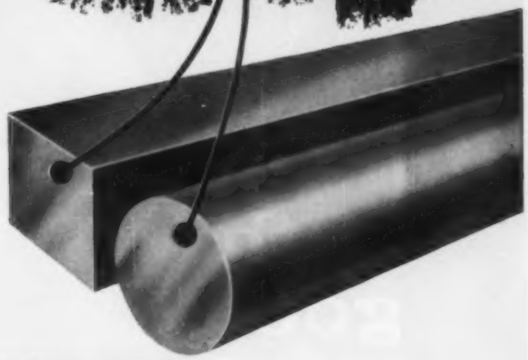

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*Latrobe's Trade Name for Vacuum Consumable Electrode Melting

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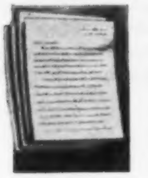


Critical Points

By the EDITORS

Effects of Radiation on Metals

One of the Unknowns of Reactor Engineering

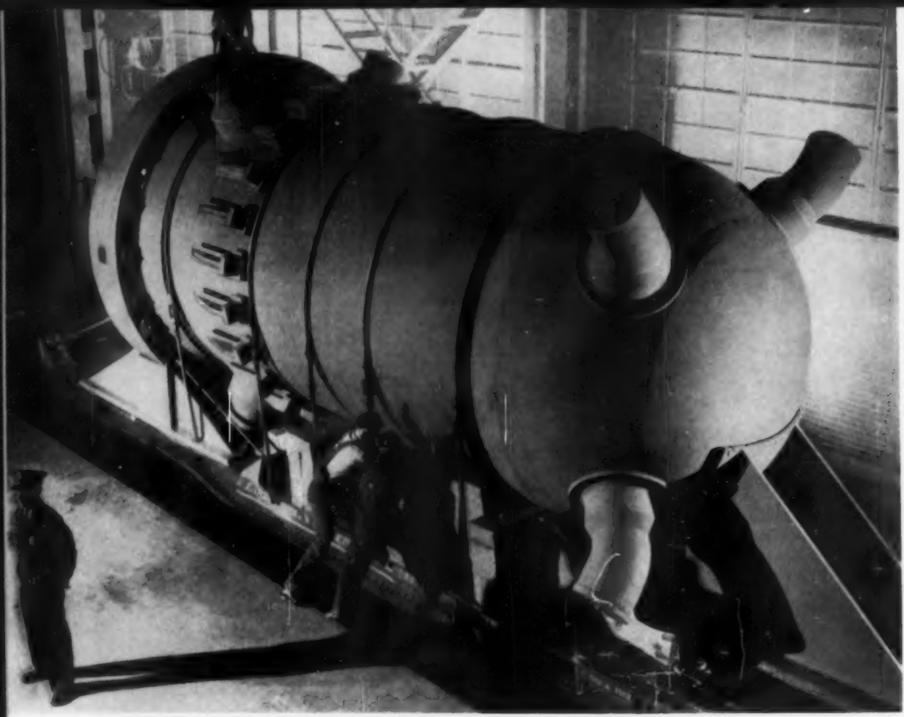
Toward mid-October, the 9th Annual A.E.C. Welding Forum was held in Chicago at the call of Frank W. Davis, metallurgical engineer of the Division of Reactor Development. These important meetings have always been highlighted by the report of the committee on welding of Type 347 stainless steel (Cb-stabilized 18-8) – welding rods, weld soundness, physical properties of weld metal and welded joints, corrosion resistance. The uninhibited presentations of the chairman, the late V. N. Krivobok, were always a matter of pleasant anticipation. His role has now been assumed by Russell B. Gunia of U.S. Steel Corp. *Metal Progress* hopes to summarize the principal findings of this eight-year study in an early issue in 1960.

Any detailed report of the proceedings must await declassification, since the meeting was "closed". It is permissible to say, however, that much of the discussion was about the welding of thin sheet or plate into assemblies with very close dimensional tolerances (on the order of 0.010 in. in 4 in.) with the utmost of uniformity and soundness. The materials are exotic and reactive metals so that the work has to be done in inert-gas atmosphere in "dry boxes". Yet percentage of defective parts was quoted by two different speakers at below 2 per 1000! The secret of success seems to be correct joint design, properly devised setup (fixtures), meticulous cleanliness, accurately adjusted and rigidly controlled automatic welding equipment, and proper cooling rate. Come to think of it, these are the essentials for sound welds in ordinary steel, yet it is surprising how easily they can get out of hand!

This same meeting instituted a program on the welding of reactor vessels, and it is about time, for these huge pressure vessels have nearly reached their limit – steel up to 8 in. thick and of size which crowds the railroad clearances. Working conditions of high temperature and pressure are serious enough but another unknown (and "unknown" is used advisedly) enters – the added effect of radiation. While a very large amount of work has been done on this problem, there are many remaining uncertainties. As H. M. Finniston of the U.K. Atomic Energy Authority's Research Establishment said in his report to the British Institute of Metals on the metallurgical developments revealed at the Geneva Conference: "Particularly disappointing were the reports on the effects of irradiation on materials. The technical difficulties of these experiments are considerable and may to some extent excuse the slow pace of advance; but perhaps more discouraging is the fact that the need for accurate control of irradiation test conditions, if we are to understand the phenomena involved, is still not fully appreciated."

Hence the importance of a two-day supplementary meeting at Chicago, also organized by Frank Davis, where a gathering of about 100 American and foreign specialists in the field discussed the status of the research about radiation effects on structural materials and the implications to reactor design.

At the risk of oversimplification, it may be said that the damage is principally done by fast-flying neutrons which knock metallic atoms out of their proper location in the space lattice (thus causing vacancies), transmute and split metal atoms into others, and cause tiny yet intense heating-and-quenching effects. All of these disorganize the regular space lattice and hence build up internal strain and consequently increase the strength and hardness of the metal at the expense of its ductility. Counteracting this is the heating effect of gamma radiation or of the surroundings at tem-



Huge Reactor Vessels Such as This Have Nearly Reached Their Size Limit (Courtesy Combustion Engineering Corp.)

peratures which may approach 1000° F. Such temperatures will anneal the strained metal and bring it back toward its original condition. Obviously the result shown by a test piece will be some balance between the hardening and the annealing effects, and this balance will depend on the neutron flux (not only the integrated or total flux but the spectrum of high energy, medium and thermal neutrons), exposure temperature and time. As Mr. Finniston implies, these are usually out of the control of the investigator. Only of recent years has it occurred to anybody to put steel samples at the inside surface of reactor vessels and withdraw them at stated intervals so the actual condition of the shell could be appraised.

At any rate, the available test results on pressure vessel steels (carbon and low alloy) are none too reassuring. The effect of moderate radiation at moderate temperature is to raise the transition temperature (temperature at which a "satisfactory" value of toughness or impact test becomes "unsatisfactory"), and to lower the toughness at working temperature. Heavy radiation may even reduce the impact strength of good boiler steel to near zero. It is little reassurance that the original properties can usually be restored, substantially, by annealing at 600° to 900° F.

One may be pardoned for suspecting that our present steels have about reached the limit of their capabilities in reactor vessels. (It is no reflection on their proved reliability in a multitude of uses to recognize that they have, even so, definite limitations.) We know that carbon is the principal strengthener of steels, but it is effective largely after precise heat treatments. Strengthening heat treatment is impossible in such thick slabs. Hence we turn to well-chosen alloying additions. But there is a limit to that. What is needed is a metal which can be designed to carry much higher stresses more safely at moderately high temperatures than can carbon or low-alloy steel.

If we can dream a bit, we might predict that some day an alloy of stable (corrosion and oxidation resisting) metals will be devised, a precipitation hardening solid solution. Its preliminary heat treatment at higher than operation temperature would strengthen it properly by precipitating a cloud of stable and slow-diffusing particles throughout the metallic crystals. At operating temperatures, the vacancies and other straining caused by radiation would be annealed out by self-diffusion as rapidly as formed – a balance struck between straining and annealing rates.

Of course, such an ideal constructional material is for the future. For the present such meetings as the one at Chicago are of value in pooling the available information on materials now known by producers, designers, constructors and users, devising better ways of getting data for designers or operators, and organizing cooperative action toward those desirable objectives.

Progress in High-Temperature Materials

René 41... New Higher-Strength Nickel-Base Alloy

*By R. J. MORRIS**

The alloy derives its strength principally from the coherent gamma-prime phase precipitate, $Ni_3(Al, Ti)$. René 41 is producible in all mill forms and it can be forged and welded. Yield strength is superior to other commercial alloys up to 1400° F. and the alloy is expected to play an important role in future jet engines and space vehicles. (A-general, T24b; Ni-b, SGA-h)

A PRESSING NEED for a better high-temperature sheet alloy has been accentuated by the desire of designers to fabricate sheet metal components for jet engines (such as compressor and turbine frames) which could be substituted for heavy forgings. The weight saving would raise the thrust-to-weight ratio. To continue to advance the power and speed of jet engines has required innovations in design and has demanded breakthroughs in materials. One of the latter is "René 41" – a new nickel-base alloy developed by General Electric Co. in its Flight Propulsion Division.

The high-temperature nickel-base alloys as a group have generally surpassed the cobalt-base alloys because of their superior yield and creep strengths, oxidation resistance, and alloying potential. Figure 1 gives yield strength as related to temperature for René 41 compared with other commercial high-temperature alloys. A typical chemical analysis for René 41 is as follows:

Carbon	0.10%	Silicon	0.10%
Cobalt	10.0	Manganese	0.05
Molybdenum	10.0	Iron	1.00
Chromium	19.0	Sulphur	0.010
Titanium	3.0	Boron	0.005
Aluminum	1.50	Nickel	Balance

Percentages of four critical elements in the

*Structural Materials Programs, Metallurgical Engineering, General Electric Co., Cincinnati, Ohio.

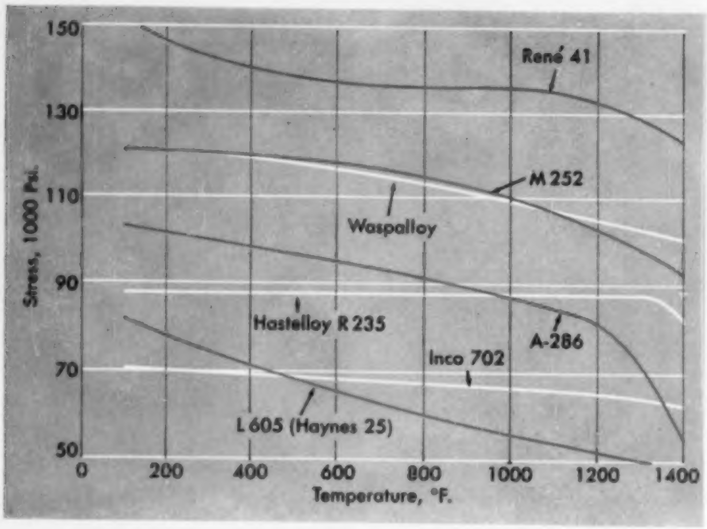


Fig. 1 – Yield Strength (0.2%) of René 41 Compared With Other High-Temperature Alloys From Room Temperature to 1400° F.

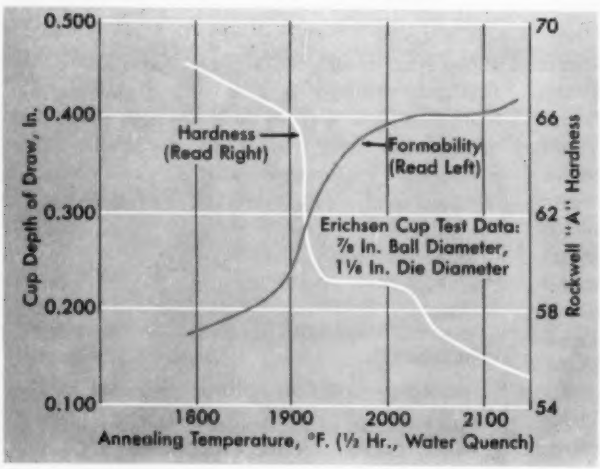
composition of some of today's nickel-base alloys are given below:

Alloy	Ti	Al	Mo	Co
René 41	3.0	1.5	10	10
Inconel "X"	2.5	0.7	—	—
Hastelloy R-235	2.5	2.0	5	—
Waspaloy	3.0	1.3	4	14
M-252	2.5	1.0	10	10
Udimet 500	3.0	3.0	4	19
Inconel 700	2.5	3.0	3	30
Inconel W	2.4	0.6	—	—
Inco 702	0.5	3.0	—	—

These alloys consist of a face-centered cubic solid solution matrix, compounds such as $Ni_3(Al,Ti)$, and carbides (one or more) of the M_6C, $M_{23}C_6$, Ti (C,N), or Cb(C,N) type. Upon cursory examination of the chemistry and compounds available, René 41 does not appear to be markedly different from other alloys. However, Fig. 1 shows the extraordinary strength of this particular combination of titanium, aluminum, molybdenum and cobalt.

René 41, as do the other alloys in this group, derives its strength principally from the coherent gamma-prime phase precipitate, $Ni_3(Al,Ti)$. Phase identification work has demonstrated that this compound is completely in solution at 1950° F. However, in order to retain it in solution, a rapid water quench is necessary so that the product is amenable to forming. Temperature of solution of the gamma prime phase is graphically indicated in Fig. 2 which depicts the formability of water quenched sheet as a function of annealing temperature. Sheets and bars are mill annealed at 1975° F. and water quenched. After all forming and welding operations are complete, the alloy is solution treated again at 1950° F. and air cooled; aging follows at 1400° F. for 16 hr. This heat treatment produces optimum tensile properties and is utilized whenever a part is designed on basis of yield strength for operation below 1400° F. Long-time applications at higher temperatures (for example, 100 hr. at 1700° F.)

Fig. 2 – How Annealing Temperature Influences Hardness and Formability of René 41 Sheet (0.047 In. Thick)



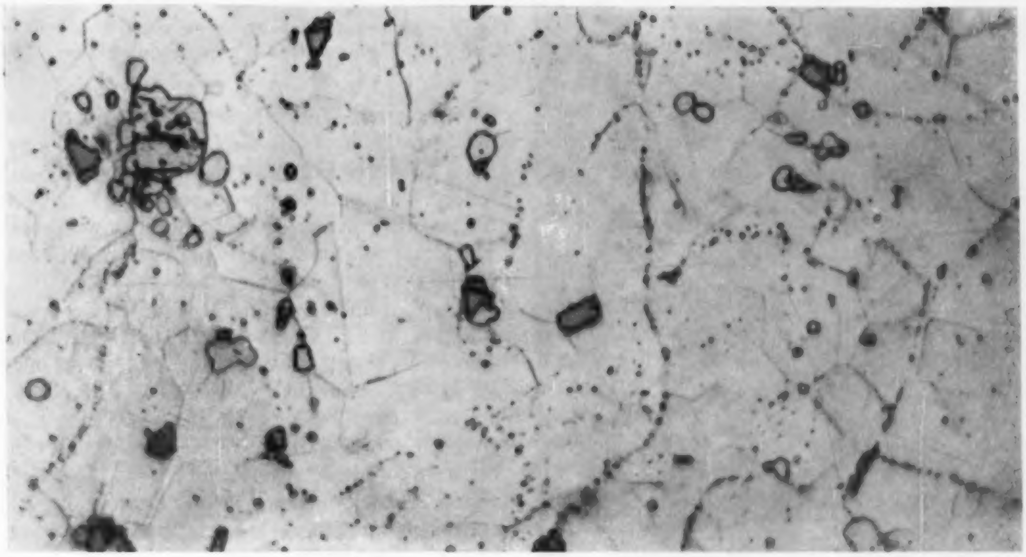


Fig. 3 — René 41 Sheet (0.060 In. Thick) in Mill Annealed Condition (1975° F., Water Quenched), Showing Large Gray Particles of TiC and Numerous Small M_6C Carbides. Etchant: Schantz plus HCl; 1000 ×

are creep limited. For applications such as these, René 41 is solution treated at a temperature of 2150° F., followed by a 4-hr. stabilizing age at 1650° F.

The other important phase present in the alloy is the carbide, M_6C. While gamma-prime phase goes into solution at about 1925° F., M_6C carbide does not dissolve until 2150° F. Thus, there are profuse carbides remaining in the microstructure after the recommended mill anneal of 1975° F. (see Fig. 3). Although they do have a slight detrimental effect upon the formability, they should not be taken into solution. If subsequent forming, welding, and heat treatment are scheduled, the sheet must never be annealed at a temperature which dissolves the M_6C. This is because dissolved carbon will precipitate as brittle $M_{23}C_6$ carbide films in the grain boundaries when the material is exposed to 1200 to 1500° F. Cracking is likely to result if there is any restraint in the system.

The secret of success here is simply that carbon must remain as M_6C carbides randomly dispersed throughout the structure. If they are dissolved, carbon will precipitate as the brittle grain-boundary film of $M_{23}C_6$ which can offer only a bare minimum of ductility. A high-temperature mill anneal at a temperature of 2150° F. also results in a relatively coarse grain which aggravates the cracking tendency.

René 41 has been produced in all mill forms — sheets and bars, billets for forgings, and investment castings. Billets have been made from single induction vacuum melted and double

Table I — Results From Experimental Extrusion of René 41*

Specimen Direction	Ultimate Strength	Yield Strength 0.2%	Yield Strength 0.02%	Elongation	Reduction in Area
	At Room Temperature				
Long.	185,600 psi.	136,500	125,500	14.0%	12.3%
Long.	168,800	132,000	116,000	7.8	7.6
Trans.	177,600	132,500	120,000	10.9	12.3
Trans.	180,000	133,000	122,000	12.5	11.2
	At 1400° F.				
Trans.	136,000	111,200	100,800	10.9	11.2
Trans.	133,340	116,000	97,060	15.6	15.2
Long.	136,540	110,400	101,400	18.7	18.0
Long.	131,740	117,860	100,260	20.3	23.8
Trans.	129,600	120,800	108,000	15.6	19.5
Trans.	129,360	114,940	103,460	26.5	27.8
Long.	131,200	113,600	104,800	13.2	16.4
Long.	138,400	121,600	108,000	13.2	21.4
Trans.	134,140	112,000	101,600	12.5	14.7
Trans.	137,600	116,800	108,800	18.7	25.1

*Heat treatment: 1950° F., 4 hr., air cooled; 1400° F., 16 hr., air cooled. Extrusion produced by Cameron Iron Works.

Fig. 4 – Experimental Forging Produced From René 41 by Cameron Iron Works, Houston, Tex.

vacuum melted (induction plus consumable electrode) ingots. The alloy has been produced in ingot sizes up to 4000 lb. Figure 4 shows an experimental forging of René 41 produced by the Cameron Iron Works, Houston, Tex. This part measures 17 in. across the flange by 14 in. long by ½ in. wall thickness and was made from a 5-in. billet. This part was produced successfully at the first attempt on a 5000-ton multiple ram press. The level of mechanical properties achieved (Table I) is outstanding.

A typical microstructure of René 41 bar stock is shown in Fig. 5 (solution treated at 1950° F. 4 hr., air cooled, then aged at 1400° F. 16 hr., air cooled). Grain size is small, A.S.T.M. No. 6, and the structure is characterized by fine, discrete, dispersed particles of carbide. Some can be seen in ghost grain boundaries. The fine $Ni_3(Al,Ti)$ compound is not visible, generally, on optical photomicrographs unless the material has been considerably overaged.

Conclusions

In summary, it has been demonstrated that René 41 is (*a*) producible in all mill forms, (*b*) can be welded and heat treated successfully, (*c*) can be forged into complex shapes, and (*d*) has yield strength superior to all other commercial alloys from room temperature up to 1400° F. Because of its outstanding properties, this alloy will play a major role in the design of advanced jet engines, aircraft and space vehicles in the coming years.

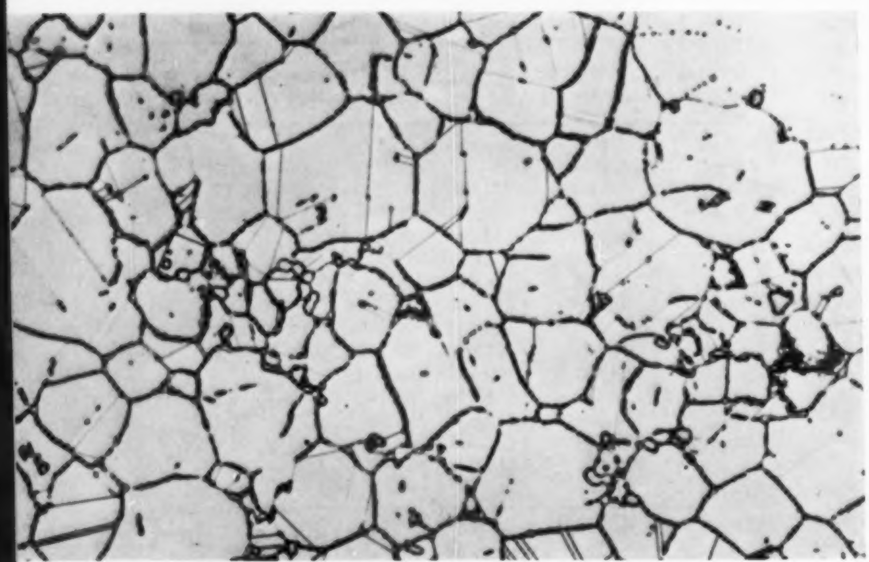


Fig. 5 – Transverse Microstructure of René 41 Bar Heat Treated as Follows: Mill Anneal, 1975° F., 4 Hr., Water Quench; Solution, 1950° F., 4 Hr., Air Cool; Age, 1400° F., 16 Hr., Air Cool. Etchant: Schantz plus HCl; 500 ×

What's New in Tungsten Research

*By W. W. AUSTIN**

Every year an estimated $2,600,000 is spent on tungsten development in the United States. Of this, 40% is sponsored by federal agencies. This article reviews current reports presented at a recent research-in-progress conference on tungsten cosponsored by the Office of Ordnance Research, U. S. Army, and nine other contracting agencies. (A-general, A9; W)

THE CURRENT INTENSIFICATION of interest in tungsten and other refractory metals was spotlighted recently by a two-day conference held at Duke University. Subjects ranged from production of high-purity tungsten and effects of trace impurities to alloys and properties; from forming and fabrication to flame spraying and protective coatings. Highlights of the conference are reviewed in this report with no attempt to give individual credits since virtually all of the papers are to be published later.

High-Purity Tungsten

A major factor in the recent "rediscovery" of tungsten as a potential structural metal is that optimum properties can be achieved through extremely high purity. Also, minute traces of such interstitial impurities as carbon, oxygen, nitrogen, and hydrogen can drastically lower strength and ductility. Consequently, tungsten of four-nines purity is considered a minimum for satisfactory properties, while five-nines purity is a desirable goal. Research on production of tungsten with this degree of purity has centered around careful purification of tungsten salts. This is followed by hydrogen reduction or electrolysis in fused halide baths. Further processing involves a choice among conventional powder metallurgy techniques, vacuum or inert-atmosphere arc melting, and more recently, electron beam zone refining. Some workers have been satisfied with the properties of powder metallurgy products for less critical applications. However, where maximum ductility combined with good strength is required, arc melted and electron beam zone-refined materials are superior. For example, comparative data from the same laboratory indicate that at 200° F. a typical coarse-grained powder metallurgy product has a tensile strength of 49,000 psi. with 1.2% reduction in area while the arc melted and impact extruded material will have 97,000 psi. tensile strength with 4.8% reduction in area. At 2500° F., the tensile strength of zone-refined tungsten is about 22,000 psi.

Electron Beam Refining

In recent months, the electron beam technique has been applied to zone refining of tungsten and other metals. This operation uses the heat generated when a concentrated beam of electrons (in vacuo and under high electro-potential) strikes the surface of the metal to be refined. The heating effect on the anode or target of an X-ray tube is a well-known example of this principle. At present, the electron beam process is limited to laboratory-scale work, but there are possibilities for expansion to larger scale operations.

For zone refining of tungsten, rod specimens

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about ⅛ in. diameter by 6 to 8 in. long are slowly traversed by an annular cathode or electron source focusing a very intense beam of electrons upon a short length or zone (about ⅛ in. long) of the specimen. Within the beam, the metal melts and rises to a very high temperature. Most impurities are volatilized in the high vacuum. Others, having a lower melting point than the base metal, remain liquid and follow the slow movement of the molten zone to the end of the specimen. The process is repeated as many times as necessary.

In this type of refining, coarse polycrystalline, or monocrystalline, structures of tungsten are usually produced. Because of the extremely high purity, exceptionally good ductility is achieved in these specimens. Room-temperature elongation values up to 12% are reported, and interstitial impurities can be reduced to a point where they cannot be detected by vacuum fusion analysis.

Effects of Impurities

Because refining and purifying improve properties so greatly, much of the current research on tungsten is devoted to evaluating the effects of trace impurities upon properties. One important approach to this problem is through measurement of typical properties as a function of the extent or degree of zone refinement. For example, electrical resistivity measurements at intervals along the specimens reveal markedly lower resistivity in zone-refined areas. This is also presented as evidence of the effectiveness of zone refining. Further evidence of the influence of purification on properties is shown in the decrease in proportional limit. It dropped from 38,000 psi. (after one pass of electron beam refining) to 17,000 psi. (after four passes). This effect is indicative of the general softening and enhancement of ductility that normally accompanies such refining treatments. Specimens that are refined twice in the electron beam are ductile at room temperature (15% elongation) but fail in a brittle manner (4% elongation) at liquid nitrogen temperatures (−320° F.). Studies are now determining ductile-to-brittle transition temperatures as a function of purity in these materials.

Alloys of Tungsten

Tungsten alloy systems may be considered in terms of alloys added primarily to purify the base metal, dispersoid systems using nonmetallic additives such as thoria, and phase equilibrium studies. When purifying with alloys, the prime purpose is elimination or stabilization of the interstitial impurities (carbon, oxygen, nitrogen and hydrogen). To this end, small additions of active metals, such as the rare earth elements, are being investigated. A good criterion of their effectiveness is the ductile-to-brittle transition temperature, while hardness measurements, metallographic, and fractographic examinations also provide supplemental evidence. Arc melting in inert atmospheres appears to be satisfactory for introducing and homogenizing rare earth additions. Though conclusive results are not yet available, these additives appear promising. However, there is some concern over possible side effects on properties.

Interest in controlling properties of tungsten by adding nonmetallic dispersoid particles is not new. Thoria additions have long been used by the lamp filament industry to control recrystallization and grain growth. Compared to commercially pure tungsten, thoriated tungsten has superior properties and is readily fabricated by conventional techniques. Aside from deliberate additions of thoria, other dispersoid particles

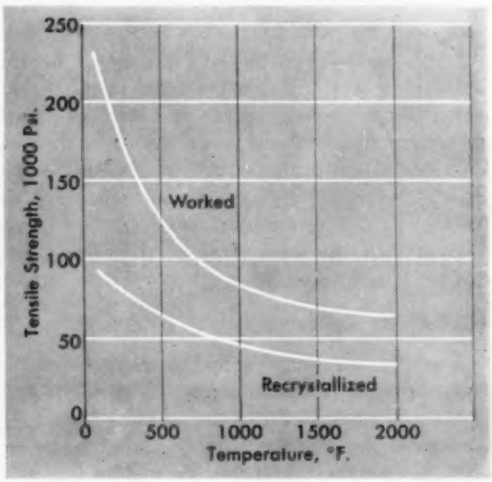

Fig. 1 – Elevated Temperature Properties of Pure Tungsten. At high temperatures, it is one of the strongest of all metals. (Courtesy Fansteel Metallurgical Corp.)

such as zirconia, boron carbide, and tungsten boride are slated for investigation. The potential of dispersoids is seen when comparing tensile properties of pure refined tungsten at 2500° F. (11,000 psi. yield strength, 22,000 psi. tensile strength, 70% reduction in area) with those of thoriated tungsten (38,000 psi. yield strength, 41,000 tensile strength, 45% reduction in area).

Fig. 2 – Tungsten Parts Fabricated by Spinning. The two reverse conical sections in the upper right (which are spun from sheet) are similar to rocket nozzles now being used. (Courtesy Fansteel Metallurgical Corp.)

Oxides are also being added to tungsten to eliminate carbon. For example, controlled additions of tungstic oxide will remove trace quantities of carbon through evolution of carbon monoxide in vacuum melting.

The broadest and most promising field of alloy investigation is in phase equilibrium studies. Here, the ultimate aim is to improve physical and mechanical properties and overcome the limitations of low ductility and poor oxidation resistance that have hindered the use of tungsten as a structural material. Immediate goals are the determination of phase equilibrium diagrams for systems, or portions of systems, that have been judged to hold the greatest potential for engineering applications. In reaching these objectives, it is not always necessary to determine complete equilibrium diagrams. Much of the desired data is obtained from spot selections of alloy compositions for preliminary studies. Gaps are filled in with additional compositions as needed. Among the binary systems, tungsten-molybdenum, tungsten-tantalum, and tungsten-columbium alloys are getting the most attention. Work on ternary systems stems from one or the other of these binary systems, and proceeds by systematic additions of a third component such as vanadium, chromium, hafnium, titanium, zirconium, rhenium, osmium or platinum.

Phase equilibria are evaluated largely by determining solubility limits, identifying intermetallic compounds, and examining various melt reactions and the mode of crystallization of alloy phases. Experimental techniques include both vacuum and inert atmosphere induction or arc melting, electron beam melting of braided wires of component metals, and levitation melting. Some difficulty has been experienced with the latter method because of the high specific gravity of tungsten. In spite of this, small heats were successfully melted in vacuo. While this method holds little promise commercially, it is excellent for making clean heats in the laboratory.

Properties of Tungsten Alloys

Some extremely interesting properties are reported for tungsten alloys. As an example, pure tungsten has long been known to possess good strength at high temperatures. Tensile strengths on the order of 30,000 psi. at 1800° F. are reported. By choosing the correct alloy composition, much higher strengths are now obtainable. The molybdenum-tungsten system, which is characterized by complete solid solubility, has alloys in both tungsten-rich and molybdenum-rich regions that possess tensile strengths of 50,000 to 60,000 psi. at 2000° F. In molybdenum-rich alloys, 0.10% Zr yields remarkably high strength at elevated temperatures. For example, one alloy, containing 25% Mo, 75% W, 0.11% Zr and 0.05% C, has a tensile strength of 98,300 psi. at 1800° F., and 73,500 psi. at 2400° F.

A very limited amount of creep and stress-rupture data was presented at this conference. In some tests of pure tungsten at 2500° F., the stress-rupture value for failure in 100 hr. is

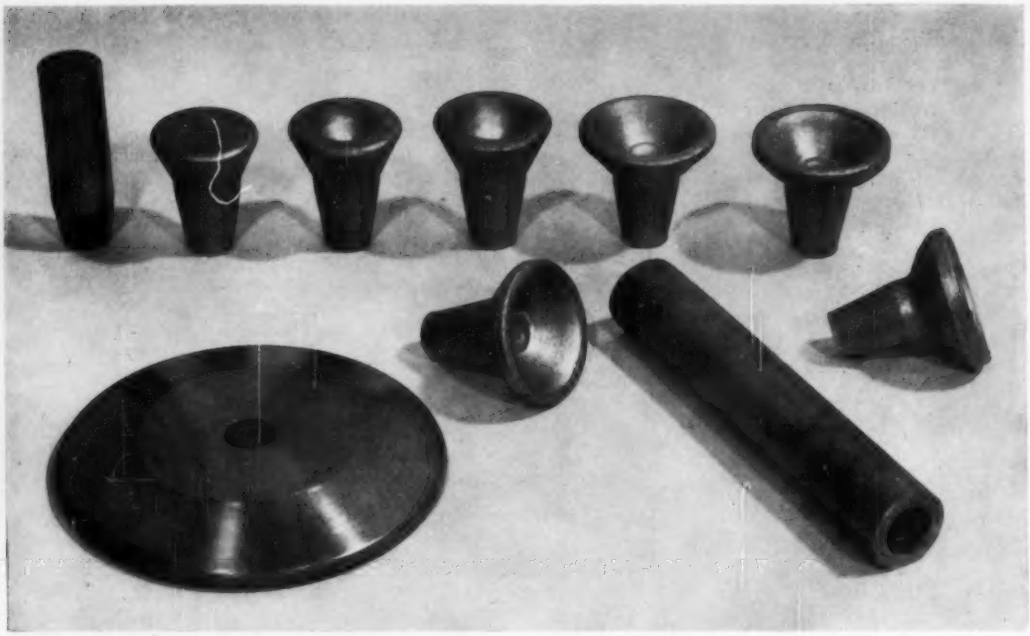

Fig. 3 – The Large Tungsten X-Ray Target Was Compacted From Metal Powder. Sintering and forging followed. Hot extrusion produced the seamless tungsten tube at right. In the background are successive steps in forging. (Courtesy Fansteel Metallurgical Corp.)

reported at 10,000 psi., while that of thoriated tungsten is given at 18,000 psi. Part of the difficulty in obtaining this type of data has been the lack of equipment which would operate for prolonged periods at extremely high temperatures. Now, several projects are aimed at improving such testing equipment. Problems associated with this work include not only the maintenance and accurate control of temperatures on the order of 3000 to 4000° F., but also the design and selection of materials for specimen holders and other components operating at these temperatures.

Forming and Fabrication

From the practical standpoint, there are some very real obstacles to commercial forming and fabricating of tungsten. This is because of its extremely high melting point and the resultant difficulty in obtaining clean homogeneous cast structures. The inherent brittleness of commercially pure tungsten is caused largely by grain-boundary films or envelopes of oxides or other nonmetallics. Eliminating the interstitial impurities responsible for these films has permitted substantial progress.

Recently, investigators have found that additions of 20 to 30% rhenium will greatly improve hot ductility and formability of both molybdenum and tungsten. This improvement is directly related to the mode of oxygen occurrence. Oxide films with low wetting angles occur in unalloyed tungsten, while high wetting-angle globules are formed in rhenium-treated alloys. Since manganese apparently acts in the same manner in counteracting hot shortness in steel, there is speculation as to whether or not it might also be effective in improving hot ductility in tungsten alloys. Such an approach seems particularly promising because of the close relationship between manganese and rhenium in the periodic table. This is scheduled for investigation along with further work on the mechanism of the rhenium effect.

In spite of inherently poor fabricability of tungsten, many workers have devised a number of reasonably satisfactory forming and fabrication techniques. For many years it has been known that tungsten can be fabricated by powder metallurgy techniques. This method is still highly regarded both as a final production method, and as an intermediate step in producing sintered bars for arc melting or zone refining. Unfortunately, the advantages of powder metallurgy in producing close dimensional tolerances and a variety of sizes and shapes are largely offset by failure to achieve optimum strength and

toughness in the finished product. Recent work has been centered around combinations of the arc casting process with various forms of hot working. Promising results have been obtained in swaging, forging, rolling, and extruding. Most of this work has been done on small ingots, 2 to 4 in. diameter, at temperatures on the order of 3000° F. Below about 1800° F. there is some difficulty with edge cracking and other evidences of poor workability. This behavior is influenced greatly by purity and alloy content.

One universal difficulty with tungsten and other refractory metals is their susceptibility to oxidation at high temperatures. Although oxidation resistance of tungsten is significantly improved by hafnium and columbium in quantities up to 10%, the oxidation problem is still very serious.

As one approach in overcoming oxidation during fabrication, a complete commercial-scale facility for hot working in an inert atmosphere is under construction. It will consist of a large argon-filled room 40 × 80 × 25 ft., with facilities for heating, handling, and hot working metals in various ways. Workers will wear space suits equipped with portable air tanks. Emergency crash-exit doors are provided as a safety measure. Although construction of such a facility is admittedly expensive (about $3,000,000) and operating costs will also be high compared to conventional fabrication costs, it is felt that the advantages to be gained both in experience and production will make the undertaking well worth-while.

Oxidation and Protective Coatings

A considerable amount of research is being devoted to the fundamental thermodynamics and kinetics of tungsten oxidation. Significant progress has been made in application of tungsten coatings by flame spraying with the nitrogen or argon-stabilized arc (plasma jet). Other investigators are working on coatings to protect against oxidation in service.

Work on oxidation fundamentals has shown that thin films of tungstic oxide initially have a protective nature. However, as the film thickens with continued exposure, it loses this property and rapid oxidation ensues. Important factors in oxidation are the rate of oxygen diffusion through the film, the high volatility of oxide at elevated temperatures, and the influence of small amounts of water vapor upon the oxidation rate and upon the oxide volatility. Laboratory work has led to the establishment of equilibrium constants for the critical reactions involved, and a reasonably complete understanding of oxidation kinetics at low flow velocities. Future work will be devoted to crystallographic and metallographic studies of oxide films and oxide-metal interfaces. Also, electrical properties of the oxides will be examined with respect to lattice imperfections and impurity atoms. It is also believed that oxidation studies at very high flow rates (equivalent, for example, to velocities of mach 2) will be needed.

Noble metal cladding was discussed. For this work, which is still in progress, metallic rhodium was electrodeposited upon wire specimens 0.070 in. diameter by 8 in. long. Conventional cleaning procedures were employed, and coatings varying from 0.0002 in. to 0.003 in. thick were deposited from an aqueous sulphate bath. As of now, various combinations of pretreatments (including chromium and rhenium plating, siliconizing and chromizing) and post-treatments (to fuse and stress-relieve the deposits) are being studied. After plating, specimens are evaluated by direct resistance heating in air until the coating fails. Results indicate that rhodium-plated specimens can be protected against oxidation to at least 1000° F. higher than is possible without any coating. Most effective is a complex coating resulting from diffusion in the solid and partially liquid states from alternate layers of chromium, silicon, chromium and rhodium. Specimens having this treatment break down after about 1 hr. at 2800° F., or after about 20 min. at 3000° F.

Tungsten Is a Promising Metal

In summary, it is clear that tungsten and the other refractory metals have some extremely promising high-temperature properties. Because of this, they have great potential as space-age materials. It is equally clear, however, that many difficulties must be overcome first. Current research has evaluated many of the properties and outlined several approaches that may be used in overcoming limitations and difficulties.

At present, practically all of the work on tungsten and its alloys is of a research or developmental nature. Apart from the lamp filament industry, very little commercial-scale production is under way. Within the foreseeable future, however, many of the current research projects will probably show enough progress to justify significant expansion of tungsten production and utilization. As a result, rapid strides will be made toward solving many of the high-temperature materials problems that are hindering progress in the fields of space flight and atomic power.

How to Fabricate A-286

*By L. J. HULL**

A typical superalloy, A-286, has been applied extensively for jet engine components by Ryan Aeronautical Co. This article records the company's experience in heat treating, forming, machining, welding, cleaning and handling the alloy. (A-general, T24b; SGA-h, 17-57)

A NEW MATERIAL that has reached the production stage and that shows superior properties for certain applications is A-286. Developed by Allegheny Ludlum for high strength and heat resistance, the alloy contains more than 50% Fe and thus has certain alloy and price economies. High strengths are produced by heat treatment, and other properties, particularly ductility in the center of larger sections, are acceptable up to 1200 or 1300° F. Since these properties are useful in fabricated weldments which need strength from 800 to 1300° F., we at Ryan Aeronautical Co. have fabricated many jet engine afterburner and gas turbine components from A-286 during the past four to five years. It is our purpose to tell something of our experience with the material during this period.

The nominal composition of this iron-base alloy is: 0.08 C max., 1.6 Mn, 0.65 Si, 15.00 Cr, 25.00 Ni, 1.25 Mo, 2.10 Ti, 0.30 V, 0.20 Al and 0.003 B. Although the material contains more than 50% Fe, there is enough nickel in it to stabilize austenite at all temperatures, and as a result no transformation occurs in the solid form. The alloy has excellent corrosion resistance up to 1300° F. in all atmospheres encountered in jet engine applications. Oxidation resistance has been compared to Type 310 stainless steel and is satisfactory for continuous service up to 1500° F. Above 1800° F., the scaling rate is higher.

Important Role of Titanium

Titanium helps make the alloy responsive to heat treatment, and A-286† attains its strength entirely by a two-stage cycle which includes solution treatment and aging. It has been shown that Ni_3Ti is the equilibrium phase of the coherent transition structure; this compound is responsible for precipitation hardening. Although other precipitates may form, they do not appear to contribute to hardening. The Ni_3Ti phase does not form above 1650° F., and when formed by overaging at a lower temperature, it readily redissolves at 1700° F. These reactions

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†Information on the physical and mechanical properties is available from Allegheny Ludlum Steel Corp., Universal-Cyclops Steel Corp., Eastern Stainless Steel Corp., Austenal, Inc., and others who produce A-286.

Table I – Effect of Solution Treatment Temperature

Solution Temperature*	Tensile Strength	Yield Strength	Elongation
1650° F.	155,000 psi.	106,000 psi.	27.5%
1800	145,000	100,000	25.0
1900	145,000	93,000	25.0
2050	141,000	88,000	22.0

*Solution treatment as indicated, oil quenched, aged 16 hr. at 1325° F., tested at room temperature.

establish a stress-relief temperature or a minimum solution treatment temperature range of 1650 to 1750° F. Hardening is optimum if the alloy is heated between 1300 and 1350° F. after solution treatment. After aging, properties are stable, and hardness is not reduced by subsequent long-time exposures to temperatures of 1300° F. and lower.

The hardening response is sensitive to the amount of titanium even when it is within the specified range, 1.90 to 2.30%. Since titanium has an extreme affinity for carbon, oxygen and nitrogen, melting presents problems in keeping the titanium free for its intended purpose. All further processing must be controlled to prevent the element from losing its effectiveness.

To solution anneal, A-286 is heated for 1 hr. at 1800° F. and oil quenched. Since it is reasonably ductile in this condition (tensile strength, 90,000 psi.; yield strength, 40,000 psi.; elongation, 40%), it can be formed and welded.

Table I shows that varying the solution treatment temperature affects mechanical properties after aging. Higher strengths result from lower solution temperatures in short-time elevated-temperature tests. Data from producers show that the strength varies with the titanium content, and that the solution treatment temperature has less effect with lower titanium than high. Higher ductilities (as measured by elongation and reduction of area) occur with higher strengths at the lower solution temperatures. Of course, higher solution temperatures mean greater creep and rupture strengths though ductility is sacrificed. Table II lists elevated-temperature test data.

With a wide range of properties available from variations in heat treatment, it would appear that the alloy properties can be "customized" to an application. For optimum properties in A-286, authorities recommend solution treatment at 1800° F. for 1 hr. and aging at 1325° F. for 16 hr.

A-286 may be purchased to the following specifications: A.M.S. 5525 A, A.M.S. 5735 C, A.M.S. 5736 A or A.M.S. 5737. It is also covered by consumer specifications such as General Electric B 50 T 12 and B 50 T 46. All of these specifications call out minimum mechanical properties after heat treatment including a stress-rupture test. Experience at Ryan has shown these specifications to be adequate in that relatively little material has been rejected when evaluated. Material failing to meet strength tests was found to be low in titanium. During the early use of A-286, some stress-rupture test failures were traced to inclusions in the materials. None of these defects have been found recently.

Stress-rupture test results are not always reproducible, and this is especially true in sheet as the gage and width of test specimens go down. Axial loading is of prime importance in this test because variables are magnified in smaller samples. It should be noted that extreme care must be exercised in preparing and testing each specimen.

Heat Treating A-286

This presents a few special problems. For one, thing, A-286 changes density during aging. Figure 1 shows a bimetallic strip of A-286 spot welded to a strip of 19-9 DL. Though coefficients of expansion for these two materials are very nearly equal, the strip exhibits a permanent bow (with A-286 on the concave side) after aging. Measurements have shown that there is about 0.6% change in density; consequently, allowances for about 0.001 in. per in. shrinkage during aging

Table II – Elevated-Temperature Properties of Aged A-286

Solution Temperature*	Test Temperature	Tensile Strength	Yield Strength	Elongation
1650° F.	1000° F.	130,000 psi.	98,000 psi.	16%
1650	1200	112,000	100,000	23
1650	1300	94,000	89,000	20
1800	1000	131,000	87,000	18
1800	1200	103,000	88,000	13
1800	1300	86,000	84,000	11

*Solution treatment as indicated, oil quenched, aged 16 hr. at 1325° F., tested at indicated temperature.

are necessary. This phenomenon practically prohibits joining A-286 to any other material before heat treating. Furthermore, the shrinkage is not always uniform. Residual stresses from machining or welding affect the direction and magnitude of shrinkage, and fixturing is often needed for parts being aged. A suitably designed fixture will allow some movement (because the density change in A-286 cannot be prevented) but will not permit distortion. In some instances, however, minor distortion can be corrected by judicious fixturing.

Carburization cannot be tolerated during heat treatment of A-286 because any extra carbon effectively reduces free titanium in the alloy. Satisfactory atmospheres include a lean exothermic gas and an endothermic gas with low carbon potential. Although neither will prevent the formation of a thin, adherent oxide film, both gases have been found to inhibit scaling during solution treatment.

Assemblies can be solution treated and aged after welding. Although quenching in oil (after solution treatment) is recommended for heavy sections, experience has shown that most sheet metal and light forging assemblies can be fan-cooled satisfactorily. Quenching distortion then rarely becomes a problem. If fixturing is used, it is generally restricted to the aging operation alone.

Forming A-286

The alloy can be readily cold formed after solution treating when the hardness is below Rockwell B-90. However, it work hardens rapidly, and stress-relieving or annealing at 1650° F. (or higher) may be needed between stages of severe forming operations. Experience has shown forming characteristics to be similar to those of 19-9 DL or Type 410 stainless alloys. Strain cracking has not been a problem, but a part should be stress-relieved after forming to prevent residual stresses from causing trouble later on.

As with many other materials, a problem may arise in forming when a critical amount of cold working results in the formation of large grains during subsequent annealing or solution treatment. Coarse and irregular grain size in A-286 may seriously affect its ductility and other properties. Though this effect appears to be negligible if the material is solution treated at 1650° F., treatment at 1800° F. may be needed for better creep and rupture strengths.

It is difficult to determine "critical" reductions in forming except by experience. (As a comparison, it ranges around 5 to 10% in rolling.) If trouble is experienced, the most practical solution lies in more frequent heating stages during forming so as to stay below the critical range in reduction between annealing operations.

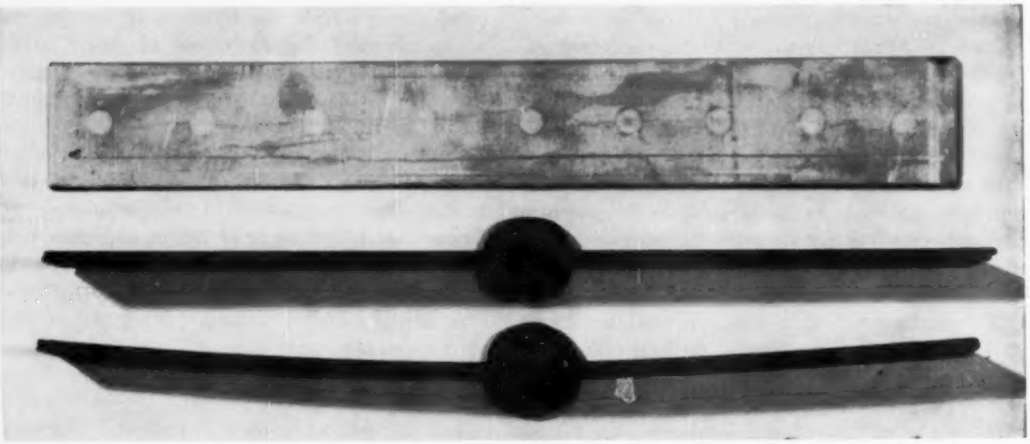
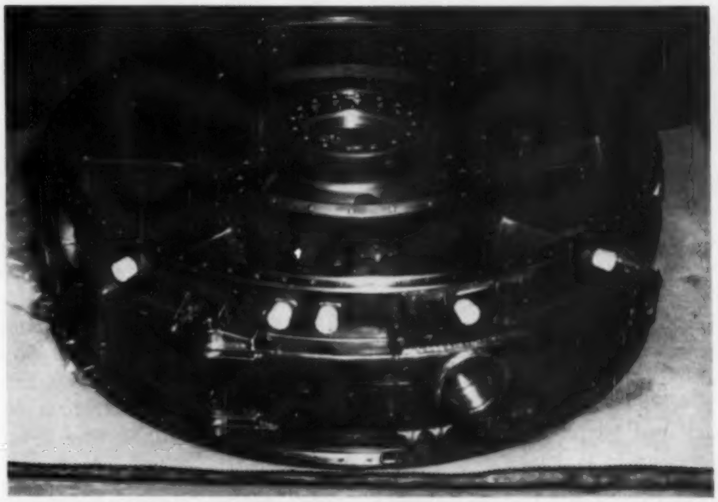


Fig. 1 — Bimetallic Strips of A-286 Spot Welded to 19-9 DL Before and After Heat Treatment. Though both materials have nearly the same expansion coefficients, density change in A-286 during aging causes strip to bend. Because of this, it is nearly impossible to weld A-286 to another metal before heat treatment

Fig. 2 — Two Designs for Jet Engine Turbine Frame. One (top) is extensively welded; the other (bottom) is the latest design change intended to eliminate most welds. In it, castings are bolted to the frame



Machining A-286

Since it is much like an austenitic alloy that work hardens rapidly, A-286 can offer much difficulty in machining. It is slower to machine than the 300 series of stainless steels, but with proper equipment and techniques it can be machined in both solution-treated and aged conditions. Metal can be removed more rapidly from aged, partially aged, overaged, or cold worked material. Carbide tool bits with a 7° positive rake have successfully cut solution-treated A-286 to depths of 0.010 in. (or more) at about 100 sfm. After aging, speeds about double this have been used for deeper cuts, using a slight negative rake. End mills of Type T-15 high speed steel are effective for milling.

Welding A-286

The alloy is difficult to weld and certain precautions must be exercised. A partial list of ideal conditions for fusion welding would include:

1. Stress-free solution-treated sections.
2. Absolute cleanliness of joint area.
3. Perfect metal-to-metal fit at joints.
4. Fixtures with inert gas back-up to hold sections in perfect alignment.
5. Joints designed to facilitate use of automatic equipment.
6. "Starts" and "stops" reduced to a minimum.
7. Joint areas separated to keep weld areas apart.
8. Similar thickness and mass of metal on either side of joint.

The ideal fusion weld would also show little or no crown, no cracks, would be narrow, sound and free from inclusions, and have the same properties as the parent metal.

Obviously, neither completely ideal conditions nor ideal welds are practical. However, A-286 has been successfully welded through attention to details and attempting to attain ideal conditions. Welds have been made with A-286 wire or Hastelloy W wire with automatic and manual heliarc methods. Metallic arc electrodes (16-25-6) have also been used. Joints made with automatic heliarc and Hastelloy W wire have shown the least amount of defects. This filler material is also preferred by operators for manual heliarc welding, and weld quality has been superior to that made with A-286 wire. Tests at temperatures up to and including 1000° F. have shown that strengths of welds made with Hastelloy W filler wire are equivalent to those made with A-286 filler.

When cracks occur, they lie in the weld and immediately adjacent to the weld. Most of the defects occur after welding and before heat treatment. It appears that there is a hot-short range; because of it, cooling stresses are sometimes relieved by the material cracking rather than deforming. Hastelloy W filler metal also may be helpful in correcting this condition.

Because welding is such a problem, much effort goes toward its elimination. To illustrate, Fig. 2 shows two turbine frames which are apparently identical. One is extensively welded; the other is redesigned so that castings can be used. This is the latest design of the J-79 turbine frame. Castings are bolted to the flanges; this eliminates many of the weld joints that could give unsatisfactory fatigue life.

Though aged or fully hardened A-286 can be welded, this procedure is recommended only for minor repairs or short welds in low-stress areas. This is because aged material is more difficult to weld.

Resistance welded joints are readily made with A-286. As in fusion welding, sections must be stress-free and fit properly. Most experience has been gained in welding solution-treated sections. Weldments are then heat treated. Tests on spot welds made after heat treatment show lower strengths. Double shear tension tests on spot welded coupons gave values of about 60,000 psi. shear, based on nugget area, when welded after heat treatment. This figure compares with about 86,000 psi. for samples which were welded before heat treatment. The alloy has also been successfully joined to other high-temperature materials by resistance welding.

Handling and Cleaning A-286

With few exceptions, most of which have been mentioned, general shop practices and handling conditions that apply to stainless alloys apply to A-286. Storage conditions are not critical, and sheet is transported and sheared in much the same manner as similar material.

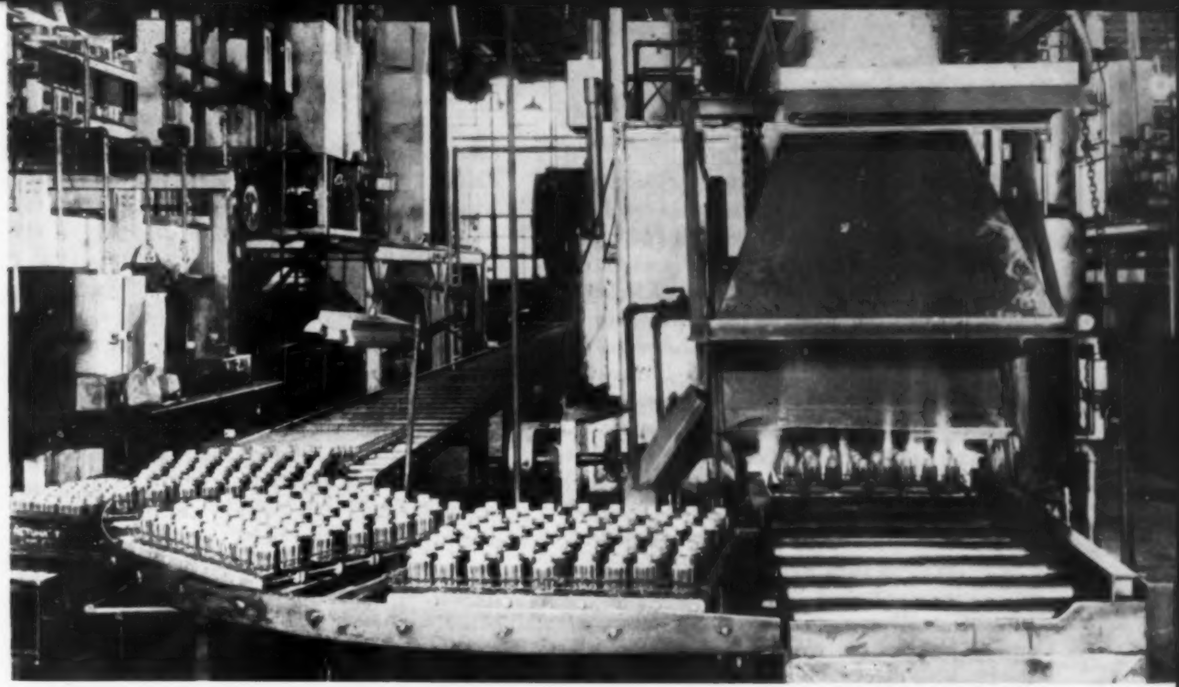
As in many other precipitation hardening alloys, aged A-286 is susceptible to intergranular attack by pickling solutions strong enough to remove scale. Solution-treated material has been descaled by a three-stage treatment. First, the part is oxidized in a salt bath at 900° F. This is followed by a 5-min. dip in 20% sulphuric acid which neutralizes the caustic salt. A 20-min. descaling in 35 to 40% HNO_3 + 4% HF at room temperature concludes the treatment. Thorough cleaning before heat treatment facilitates scale removal afterwards. In many instances, descaling may not be necessary or can be carried out mechanically.

Conclusion and Comments

It should be pointed out that the experiences listed and recommendations made here are results of the methods used or developed at Ryan Aeronautical Co. in fabricating A-286 jet engine components. There are, without question, many other methods of fabrication, techniques, and know-how that are as good or better than those discussed. It is hoped that this paper will stimulate discussion and other contributions to the field of fabrication of high-temperature materials.

It would not be right to leave the subject without a few comments on the future of A-286. Experience indicates it to be a "proven" alloy – well past the "test flight" stage. It may be the next skin material for high-mach planes or for missiles. Its use in jet engines will, no doubt, be expanded. Brazed or welded lightweight structure, such as honeycomb or "Mini-Wate", may incorporate A-286. Its properties look interesting for application in the cryogenic field.

With these applications and other future uses for the material must come more data on properties and processes. Engineers need more data on compressive and shear properties at room and elevated temperatures. Missile designers need more data concerning extremely short-time properties. All this will help to complete the research, development, testing, fabrication and use cycle for alloy A-286.



Furnace Trays Being Used in a Roller Hearth Furnace. This is a Holcroft furnace installed at Amplex Div., Chrysler Corp.

Designing Trays for Roller Hearth Furnaces

*By GEORGE W. WARDWELL**

The heat treating process and the configuration of the part to be treated are important in tray design. They largely determine the design features and the materials to be used for the tray. (W27p)

TODAY, MANY MASS-PRODUCTION NEEDS are served by the roller hearth furnace. Used widely for heat treating because it can continuously process large volumes of work, this type of furnace has conveyer-type rolls throughout its length. They allow the work to move through the furnace at controlled speeds and with very little friction.

Because high temperatures soften most of the work, the workpieces themselves cannot be allowed to rest directly on the rolls. Instead, they must be supported on a furnace tray. This item has to be strong enough to span the gap between the furnace rolls and resist the compressive force exerted by the workpieces it supports.

Far more than accessories, trays are actually the basic carriers in the handling system. Their design can substantially affect furnace capacity, thermal efficiency, processing time and production rates. If designed properly, trays can invariably increase efficiency and produce substantial savings in operation.

What, then, are some of the basic requirements for a strong, durable furnace tray? In essence, design and material are the important factors. Design features should be planned for the specific application, and the material should be chosen to fit the needs of the design. Balancing design requirements, some of which can be contradictory, is a problem not easily solved as this article will show.

*Chief Engineer, Rolock Inc., Fairfield, Conn.

Weight and Operation Costs

Weight is of prime importance. For efficient operation, it is obviously desirable to load a furnace as much as possible without endangering furnace structure. Since the tray goes through the identical heating and cooling cycles as the work it carries, the furnace is required to heat and cool both work and tray. Therefore, each pound of tray that goes through the furnace costs as much in furnace operation as does each pound of work. Trays that are more massive than necessary add to operational cost and lower efficiency.

Strength and Weight

Factors other than weight must be considered, of course. It must be kept in mind that the tray protects workpieces as they pass through the furnace, and keeps parts from falling between the rolls. The tray must also have enough strength to prevent a workpiece from deforming while it spans the distance between rolls.

The strength to be incorporated in the tray's design is decidedly related to the size and nature of the workpiece it is intended to carry. Spacing between the furnace rolls is also important. For example, consider a very large and massive workpiece whose length in the direction of travel exceeds the distance between the rolls. If it is also strong enough to resist sagging between the rolls, it can be adequately carried in a fairly light tray. Strength would be needed only to prevent the tray from being indented by the compressive force on the furnace rolls as it passed over them. In such an instance, tray members would be designed to present a broad surface to the furnace rolls. The section depth would not have to be great since there would not be any appreciable bending force.

In another application, the load might consist of a multitude of small parts, such as a number of steel balls or shafts. While such items might be relatively light, over-all, they would exert a very substantial bending force on the span of the tray as it traveled between the centers of the furnace rolls. Here, the ability of the tray to resist bending is more important than its ability to resist a compressive force on the rolls. To achieve this needed resistance to bending, trays should be built of members that are relatively thin in cross section, but deep in section.

In tray design, it is most important to consider the cooling practices to be used in the application. Often, the tray is quenched (with its load, of course) in such mediums as quenching oil or even cold water. Naturally, the bottom edge of the section enters first and begins to contract, while the top is still in a heated and expanded state. This subjects the entire section to severe internal stress.*

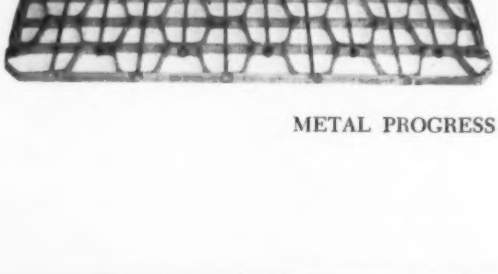
Such stresses frequently result in cracking or in serious distortion of the metal in the tray. For this reason, trays are often designed of members that are uniform throughout in cross section. However, if the principle were followed to the letter, the tray would be built of parts that were heavier than actually required. This would add unnecessarily to the tray weight.

Low heating and cooling factors can be included without sacrificing lightness by proper consideration of the load-carrying ability of the tray. Many times, this aim can be achieved by building all members extending in any one direction of the same cross section. Then, through uniform heating and cooling, internal stresses are eliminated in that direction. Another method for protecting the tray from this type of distortion is to assemble it with loose joints so that parts can move with respect to one another. However, this is difficult to achieve without sacrificing strength.

A good example of a well-designed loose-jointed structure is the serpentine tray shown in Fig. 1. Its basic concept has been used in trays ranging from about 1.5 to 150 sq.ft. Also, for applications of this type (where load characteristics permit), pressure welded trays built of round rod are highly desirable. Round rods are

*The size of the effect can best be illustrated by discussing a typical furnace tray alloy such as wrought Inconel (72% Ni, 15% Cr). Its expansion coefficient is 0.0000102 in. per in. per °F. When heated from room temperature to the 1600 to 1700° F. range, such a piece would expand about 3/16 in. for each foot of length. Slowly quenched in oil as described, this alloy would shrink an equal 3/16 in. per ft. The dimensional difference between the members that would occur could only be accommodated by bending, stretching, or compression of fibers. Equilibrium is restored by submersion of the entire section. This effect is, of course, correspondingly more severe with each additional foot of length.

Fig. 1 – Serpentine Tray Showing Loose-Joint Construction. A tray of this type is designed to resist bending forces that can occur in the span between rollers



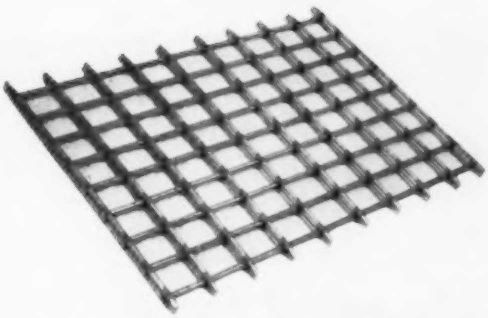


Fig. 2 – Furnace Tray Built From Round Rods. Multiple layers give added strength

free from thin leading edges that might quench too rapidly. Where adequate beam strength cannot be obtained with a single round rod, multiple layers can be used (see Fig. 2). Again, thin leading edges are avoided.

Carburization Is a Problem

Gas carburizing is a familiar heat treating process which can also be performed in a roller hearth furnace. Again, trays must be used. For this application, however, they must withstand carburization as well as heating and cooling stresses. Carburizing can, during the tray's first few trips through the furnace, improve the properties of the tray alloy. However, subsequent and repeated trips can harden and embrittle the alloy, lessening its ability to withstand mechanical shock and other abuses.

In such instances, it is again desirable to use round rods to build the tray. Since carbon penetrates inward, its detrimental effect is not fully felt until it reaches the core. The greater distance from surface to core provided by the round rod section makes complete penetration more difficult than in a rectangular section of the same total volume.

Pressure welding is also highly desirable with this type of environment. In other welding procedures, weld metal must be added to the joint. It is difficult to provide a completely continuous metal structure free from crevices into which carbon might penetrate.

Proper Materials Are Essential

When subjected to furnace conditions, many initially strong materials fail rapidly. Subsequent losses of strength and ductility may seriously impair the operating life of the equipment. Other materials become extremely brittle when heated. This impairs their ability to withstand shocks resulting from the rough handling usually encountered in most heat treating processes.

In general, the ability to retain good ductility is the most important property for a furnace tray material. Though strength is also very important, it will not itself insure successful tray operation and satisfactory life. If a brittle, glass-like structure develops, it may not only cause rapid break-up of the tray, but make it impossible to repair. However, repairs to a tray are possible if the material is still ductile. Routine maintenance also contributes greatly to tray life. Wrought materials, by their nature, impose no limitations of thinness or thickness. This allows the designer freedom to exercise his best judgment in regard to the assembly of parts and the proportion of parts best suited to the particular application.

Wrought material for trays should have a fine to medium grain size and a normal carbon content of 0.06%. For use up to 1800° F., a ratio of about 33% Ni and 21% Cr (we use Incoloy) is highly recommended. When trays are to be used at higher temperatures, nickel should be increased to about 72%. Inconel is used for this application.

Chromium provides a tightly adhering, close-knit scale on the surface of the metal. This scale protects the part from oxygen, carbon or any other elements that might enter and harm the alloy. Nickel is used for toughness and strength at high temperatures.

Also important, the designer must be sure the supply source is reliable, and that the material supplied is consistently uniform throughout. Variation in grain size and carbon content, particularly, may cause excessive cracking and break-up of an alloy in service, or give confusing results in its performance. This can result in failure of a design which would otherwise have been perfectly satisfactory.

To sum up, in designing the lightest possible tray for a given type of operation, the designer must make a well-balanced compromise. His decision should rest between the section which can best carry the load and the section which can best resist the effects of quenching, carburizing, or other environments that might affect mechanical configuration. He must also determine the proper material for the tray. The result should always combine the elements of good design to achieve a proper balance between initial cost, tray life, and tray weight to insure the maximum in efficient, economical operation.

Solid-Fuel Rocket Chambers for Operation at 240,000 Psi. and Above—II

*By M. E. SHANK, C. E. SPAETH, V. W. COOKE and J. E. COYNE**

When a rocket chamber failed unexpectedly during a hydrostatic test, an intensive investigation was launched. Water used in hydrostatic testing proved to be responsible, causing delayed, hydrogen-induced fracture. In the end, this extensive work showed that solid-fuel rocket cases with tangential stresses of 240,000 psi. are practical. Stresses of 260,000 psi. appear possible if small plastic strains can be tolerated. (Q26, T2p; SGA-h, TS, *II*)

Design and construction of solid-fuel rocket chambers to operate at 240,000 psi. tangential stress is not simple, as last month's article showed. To summarize, awkward details of design were entirely eliminated. The full-size chamber, 40 in. in diameter and 6 ft. long, was made from H-11 vacuum melted steel without longitudinal seams. On hydrostatic testing, one full-scale vessel failed (with the fracture origin in parent metal) at a stress lower than it had previously withstood. Preliminary investigation (see last month's article) seemed to indicate that delayed failure, induced by hydrogen, was responsible. To substantiate this, much additional work was required. It is described here.

The Effect of Hydrogen in Steel

At this point it would be well to discuss some of the recent research work that has been carried on concerning the nature of hydrogen embrittlement, cracking, and delayed failure in steel. Some of the most significant has been carried out by Troiano and his co-workers and by Sachs.† No complete review will be attempted here, but pertinent theoretical and experimental developments will be briefly covered.

If specimens containing small amounts of hydrogen in solution are tested by conventional methods, they may display the normal properties of strength and ductility. Yet, delayed failure in the same material will occur under long-time loading in the presence of a stress concentration. Moreover, the fracture strain of such material is reduced. The effects of hydrogen embrittlement are known to decrease with increasing strain rates, and will also decrease and finally disappear as lower and lower testing temperatures are em-

*Dr. Shank is associate professor of mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass. The others are associated with Pratt & Whitney Aircraft. Mr. Spaeth is senior design engineer, Mr. Cooke is supervisor, Materials Development Laboratory, and Mr. Coyne is project metallurgist, Materials Development Laboratory. This is the second article in a series of two. The first appeared last month.

†Last month's article contains all references.

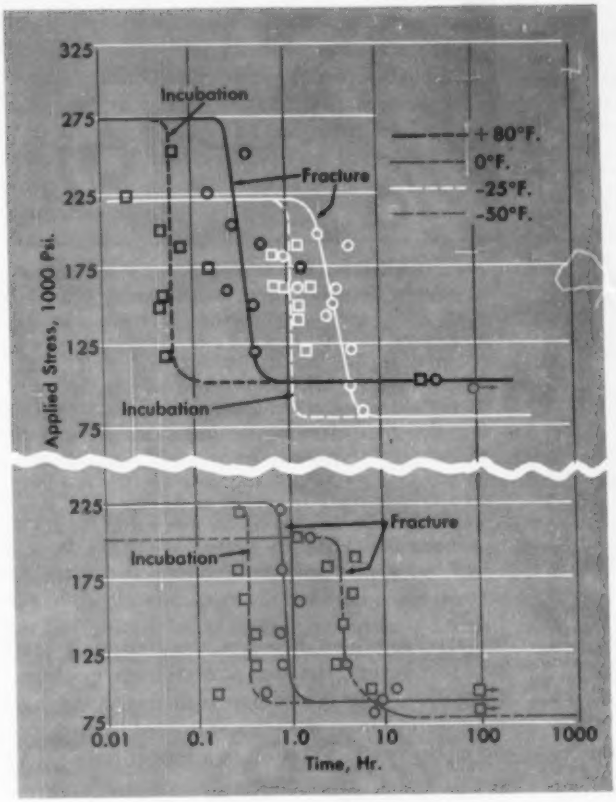


Fig. 9 – Static Fatigue Curves for Hydrogenated High-Strength Steel Specimens Tested at Various Temperatures. The specimens were cylindrical and contained sharp notches. The material was A.I.S.I. 4340 aircraft quality steel heat treated to a smooth tensile strength of 230,000 psi. After Troiano

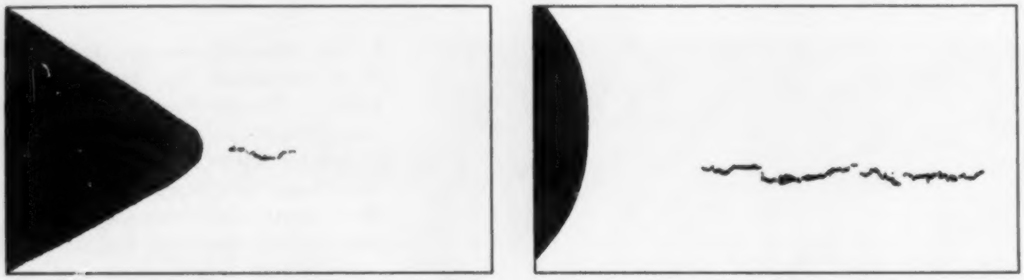
ployed. Austenitic steels are to all practical purposes immune from hydrogen embrittlement. It has been found in ferritic steels that retained austenite is not a factor. Delayed failure will occur in ferritic steels in the absence of retained austenite.

If the delayed failure tests are performed for a steel of given tensile strength (as measured in smooth specimens) with fixed concentration of hydrogen in solution and fixed notch acuity of the test specimen, three characteristics are revealed. First, there is an upper stress level corresponding to the notch tensile strength of the material for short-time loading. Second, there is a static fatigue or lower limit of stress below which failure will not occur in any length of time. Third, there is an intermediate range of stress over which point delayed failure takes place. It has been discovered that there is an incubation time for crack initiation. This incubation is relatively insensitive to applied stress level and is longer for lower temperatures, other conditions being equal. Features of the delayed failure curves and incubation time are shown in Fig. 9.*

Troiano has hypothesized, and supported by experimental evidence, that it is hydrogen in solution and not hydrogen occluded in internal voids that is damaging. This is shown by the fact that pre-cracking of a specimen raises the static fatigue limit by creating voids that act as hydrogen traps. This decreases the amount of hydrogen available for solution and diffusion in the lattice. It has been further demonstrated that under stress in the presence of a stress concentration (such as a notch or void) hydrogen will diffuse to the point of maximum triaxiality of stress. Thus, the process involved is not one of classical diffusion, but rather diffusion in the presence of a stress gradient. For a sharply notched specimen the point of maximum triaxiality lies close to the surface near the root of the notch. For rounded notches the point of maximum triaxiality of stress lies increasingly away from the surface of the stress concentration. After the incubation period, the crack starts at this point, and propagates both outward to the surface of the stress concentration and inward (see Fig. 10). This occurs whether the triaxial stress state is elastic or plastic, but the latter instance is more damaging.

Troiano has shown that the activation energy for the incubation process is 7610 cal. per mole. This is in fair agreement with the activation energy of 8900 cal. per mole for the diffusion of hydrogen in alpha iron. Thus it seems that the incubation period is controlled by the rate of the stress-induced diffusion of hydrogen. Since the incubation period is diffusion controlled, it is reversible. Thus by alternately stressing for a time less than the normal incubation period, and following by aging for relatively long periods of time, integrated incubation periods from two to

*Numbering of figures is continuous with last month's article.



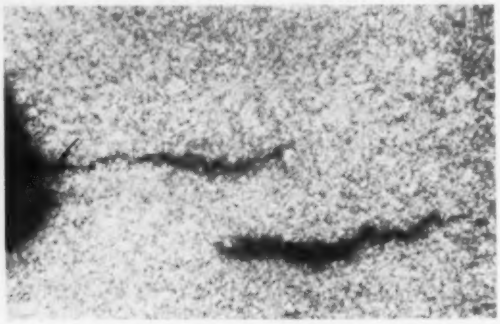


Fig. 10 – Cracks Observed by Troiano in Notched Specimens Sectioned After Static Loading. Specimens had been hydrogenated, cadmium plated, and baked at 300° F. for 12 hr. (left) and ½ hr. (right). Applied stress, 240,000 psi. (left) and 225,000 psi. (right). Longitudinal section. 100 ×. In the sharply notched specimen (radius – 0.001 in.) the area of maximum triaxiality lies close to the notch surface and the initial crack forms here. In the rounded notch (radius – 0.01 in.) the area of maximum triaxiality is further from the crack. The cracks then travel outward to the surface and inward to the interior of the specimen. Left is Fig. 7 reproduced from November issue

four times the normal period can be obtained before crack initiation occurs in a specimen.

After the crack is started, its growth is discontinuous. Further crack growth must await diffusion of hydrogen to the new region of maximum triaxiality of stress beyond the crack tip. The process is repeated until a crack length is reached which is critical with respect to the gross structure. Failure then occurs.

Thus, the time for delayed failure is a function of stress level, notch acuity, hydrogen concentration, and temperature. Distribution of hydrogen from point to point in the material is also important. Consider, for instance, two specimens of the same material with equal stress concentrations and containing the same amounts of hydrogen. One specimen has been left in the as-charged condition so that there is a heavy concentration of hydrogen at the surface near the notch root, and little if any hydrogen away from the surface. The second specimen has been baked to distribute the hydrogen evenly throughout the section. Then, for equal stress levels, delayed failure will occur at a shorter time in the baked specimen. This is because the distribution of hydrogen is fairly even in the baked specimen. It does not have to diffuse very far to concentrate in the triaxially stressed region at the tip of a stress concentration, no matter where this stress concentration may be. As the crack grows, hydrogen is always distributed ahead of it. In the unbaked specimen, however, the crack will soon progress beyond the area of high hydrogen concentration. For it to progress further, hydrogen must diffuse from the surface inward toward the tip of the crack. This takes a longer time.

Water as a Cause of Failure

In the light of the theory and the supporting experimental evidence, failures of the miniature test vessels and of the full-size missile casing were re-evaluated. All of the subsize test vessels which displayed no weld or other defects had failed in the parent metal at high stress levels, two being well above 300,000 psi. In every instance failure began in the parent metal on the inside exposed to the water.

The full-scale vessel which had failed had a more complicated history. However, it was again certain that no weld or other normal structural defect had played a part in the failure. It had clearly originated in the parent metal from a spot on the inside surface of the vessel where a flow-turning defect had been ground away. There had been clear evidence of pitting corrosion. Considering what is known about the effect of hydrogen, the features of Fig. 7 (reproduced above, left) assume particular significance. The right-hand pit has two cracks radiating from it. One crack extends into the pit. However, the portion of this crack that is most widely opened is somewhat removed from the pit sur-

face. The portion of the crack that extends into the pit surface is discontinuous and rather narrow. Just below this pit there is another crack which does not open into the pit surface. In Fig. 7 this crack is seen to be separated from the pit by about 0.005 in. The features described are typical of the pitted regions in the large fractured casing. They are also very similar to Fig. 10, from the work of Troiano.

One other general feature of importance is noted. The ground or repaired areas were comparatively free of any oxide scale. The remainder of the vessel interior had a fairly well-developed, if rather thin, oxide scale.

In view of the foregoing, it was hypothesized that galvanic action leading to local hydrogen charging had been important in the failures originating in parent metal in both the test vessels and the full-size casing. In the full-size casing, the anodic areas had obviously been the pits at the four spots repaired by grinding.

The cathode consisted of at least the remaining area of the ground spots. It does not seem likely that the entire interior surface (comprising about 70 sq.ft) acted as cathode in room-temperature tests. Because of the small total area of the pits, the ratio of cathode to anode area is high. The current density at the anode would therefore be relatively high. In the cathode area, current density would be greatest in the region immediately surrounding the anodes. Here hydrogen would be released and would diffuse into the steel. The pitted areas provided points of stress concentration. The maximum elastic stress concentration factor for a circular hole in a plate is 2.5 in a biaxial stress field such as exists in the present cylindrical tank. Just adjacent to the surfaces of the pits would be the maximum regions of triaxiality of stress. The hydrogen charged in the steel by galvanic action would diffuse to these regions.

Ordinarily such a galvanic reaction does not produce very much hydrogen. Thus the general level of hydrogen could be very small but the local hydrogen concentration around the pits might be very high indeed. A very small volume of material is involved. With continued testing, cracks could grow in size from the point of maximum triaxiality bordering the pits. Finally they will reach the pits, and also travel away from the pits. When a crack length of sufficient size is attained, gross catastrophic failure will occur.

In the small test vessels, the same mechanism could occur in hydrostatic testing with water. Here the anode would be the material in the vicinity of origin of failure. The interior area in these vessels would be about 6 sq.ft.

A program of investigation to support or refute

Table I – Subsize Vessels Burst-Tested in Delayed Failure*

No. 14—No Protection
Sustained load:
201,500 psi., 60 min.
224,000 psi., 53 min.
Tangential bursting strength—224,000 psi.
No. 15—No Protection
Sustained load:
275,000 psi., 1 sec.
206,000 psi., 5 min.
252,000 psi., 5 min.
172,000 psi., 180 min.
172,000 psi., 420 min.
229,000 psi., 420 min.
252,000 psi., 16 min.
Tangential bursting strength—252,000 psi.
No. 16—No Protection
Sustained load:
235,000 psi., 840 min.
256,000 psi., 135 min.
Tangential bursting strength—256,000 psi.
No. 21—Inside Coated With Heresite Primer
Sustained load:
241,000 psi., 810 min.
Then depressurized; water left in.
262,000 psi., 1 min.
Tangential bursting strength—262,000 psi.
No. 22—Inside Coated With Heresite Primer, Outside Submerged in Water Bath
Sustained load:
218,000 psi., 870 min.
Then depressurized; water left in.
240,000 psi., 75 min.
Tangential bursting strength—240,000 psi.
No. 23—Inside and Outside Coated With Heresite Primer
Tempered in Vacuum to Reduce Hydrogen
Sustained load:
4 cycles of 3 min. each to 264,000 psi.
264,000 psi., 585 min.†
Rest for 57.4 hr.; water drained.
264,000 psi., 870 min.†
Rest for 14.25 hr.; water drained.
264,000 psi., 240 min.†
275,000 psi., 345 min.†
Rest for 8.75 hr.; water drained.
275,000 psi., 135 min.†
Rest for 8.0 hr.
275,000 psi., 435 min., then pressure increased hourly in steps over 810 min. Failure at 318,000 psi., after 45 min. Pressurized with oil.
Tangential bursting strength—318,000 psi.

*Initial stock (all H-11, air melted) contained 1.3 ppm. of hydrogen prior to fabrication.
†Vessel immersed in water.

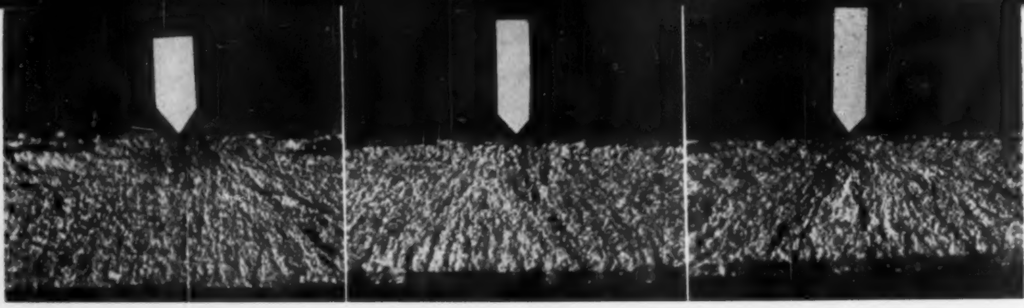


Fig. 11 – Fracture surfaces of subsize vessels. (Left) – vessel No. 14, 24 ×. (Center) – vessel No. 15, 22 ×. (Right) – vessel No. 16, 22 ×. All were pressurized with water. Fractures originated in parent metal on inside surfaces. In each instance there is at the immediate origin (arrows) a dark area, indicative of hydrogen induced fracture. Note absence of shear lip at fracture origins

the hypothesis was immediately launched. It was known that the presence of high mineral content or of phosphides, sulphides, or acids in the water would increase its electrolytic activity. This was checked, and results were negative. Temperature is also important, hot water being a better electrolyte than cold water. The second series of tests in the large vessel had been performed at 360° F., with hot glycerine which contained some water. It seems only likely that any hydrogen charged into the vessel at that time would have been diffused away from the pitted areas long before the final series of tests, which took place three months later. However, the corrosion which served as the source of final failure may have been initiated in these high-temperature tests. The pits, if so developed, would serve to center future corrosion at the same location in the final series of tests at room temperature. This, of course, cannot be proved, but it seems logical.

Six subsized vessels, exactly like those previously employed, were manufactured for testing. Again, the material was H-11 analysis, but air-melted stock. The hydrogen content was 1.3 ± 0.1 ppm. before fabrication of the small vessels. Heat treat and fabrication procedures were as used in the large casing.

Hydrostatic tests (with water as the pressurizing fluid) were run on each of these vessels. Details are summarized in Table I. The first vessel, No. 14, was stressed tangentially at the thinnest section of the wall to 201,500 psi. for 60 min. and 224,000 psi. for 53 min., at the end of which time it fractured. The origin of failure was parent metal on the inside cylindrical surface about 1½ in. from the central girth weld. Examination of the origin showed a dark area which extended into the thickness of the material about one-quarter of its thickness, or roughly about 0.010 in. Chevron markings were developed away from the point of origin, and a shear lip was present everywhere except at the point of origin. The fracture is shown in Fig. 11 at left. The darker area at the origin is typical of hydrogen-initiated failures. It is darker because the area affected by hydrogen-induced crack propagation has a finer texture than the surrounding fracture area which propagates at high velocity.

The second vessel in the series, No. 15, was loaded seven successive times at different stress levels. The initial loading was to 275,000 psi. tangential stress. Following this, it was held to 206,000 psi. for 5 min. In successive tests stress was varied for different times. It was held 420 min. at 229,000 psi. and fractured after 16 min. at 252,000 psi. The fracture surface is shown in Fig. 11 (center). Fracture started in parent metal some distance from the welded joint. Again, the dark area typical of hydrogen-induced fracture was present.

A third vessel, No. 16, carried a sustained tangential wall stress of 235,000 psi. for 840 min. Following this, it was loaded to 256,000 psi. tangential wall stress for 135 min. whereupon it fractured. Again, the origin of fracture was in the parent metal about 1½ in. from the circumferential weld. As shown in Fig. 11 (right), there was a dark area at the origin, indicating fracture originating from hydrogen.

The next vessel to be tested, No. 21, was coated inside with Ochre Heresite primer (A.M.S. 3108) to protect it from electrolytic attack by the water. It sustained a maximum tangential stress of 241,000 psi. in the cylindrical portion for 810 min. Following this it carried a stress of 262,000 psi. for 1 min. before failing. Fracture began in parent metal under the inside surface about 1⅞ in. from a weld. The area containing the origin of fracture was badly bulged (see Fig. 12). It will be noted that there is no discolored area at the origin of fracture. In fact, the fracture origin has a shear lip running alongside it, indicating that fracture must have initiated beneath the surface, probably at some sort of inclusion. The material contained 3.2 ppm. hydrogen. Examination of the inside surface showed that the paint coating was only of fair quality so far as

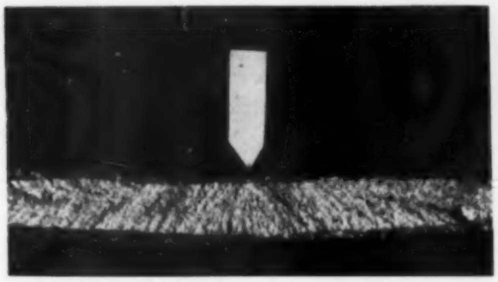


Fig. 12 – Fracture of Test Vessel No. 21. It had been coated with primer on the inside to prevent contact with water. This had been subjected to sustained loading and fractured at a stress of 262,000 psi. The origin of the fracture was in parent metal under the inside surface about 1⅞ in. from the nearest weld. There is no discolored area at the origin of fracture. Shear lip is seen along both edges of the fractured surface, even at the origin. There is no discolored area indicative of hydrogen induced failure. 10 ×

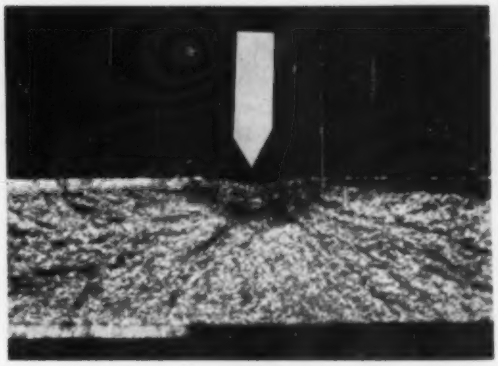


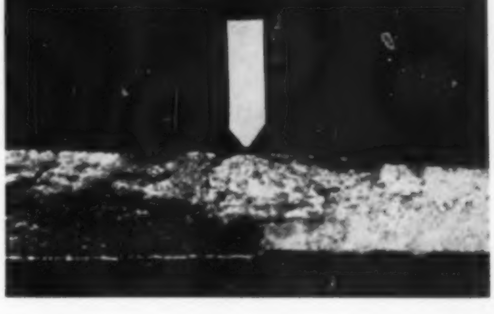
Fig. 13 – Fracture Surface of Test Vessel No. 22. This had been coated with primer on the inside and pressurized with water, while at the same time the outside surface was bathed in water. Failure was at 240,000 psi. maximum tangential stress after sustained loading. The origin of fracture was in parent metal at the outside, and displays the dark area typical of hydrogen induced fracture. There is also a pit. 16 ×

coverage was concerned. There were numerous intermittent areas which were free of paint, having been apparently inadequately cleaned prior to paint application. Though some areas were exposed to water inside the vessel, it would seem that there was enough paint coverage so that only a small amount of potentially cathodic area was available. This undoubtedly prevented any substantial degree of electrolytic action and charging by hydrogen. Subsequent check showed the hardness to be Rockwell C-55. It had been inadvertently tempered at too low a temperature, probably 950 to 1000° F. All other vessels had a hardness of Rockwell C-50 to 51. This would indicate vessel No. 21 to have a higher tendency to crack initiation from mechanical causes such as inclusions.

The fifth vessel in the series to be tested, No. 22, was also coated on the inside with primer. However, the vessel itself was submerged in a water bath with the outside unprotected. It sustained a maximum tangential stress in the clyindrical portion of 218,000 psi. for 870 min. and of 240,000 psi. for 75 min., following which it fractured. The origin of fracture was in the parent metal 2⅞ in. from the weld. It is of the greatest significance that the fracture originated on the *outside* of the vessel, which was submerged in water and unprotected. As shown in Fig. 13, there is the dark area typical of hydrogen-induced fracture at the origin. There is also a relatively smooth pit at the origin about 0.0025 in. deep. The average hydrogen content of the steel was found to be 2.0 ppm.

The final vessel in the series, No. 23, was coated both inside and outside with primer. It was cycled four times (3 min. each time) to 264,000 psi. Water again was the pressurizing medium, and a water bath was outside. Following this, the vessel was held at 264,000 psi. for 585 min. It was then tested at varying pressures and times as listed in Table I. Rest periods of varying times followed most tests. After this, the water was removed from both inside and outside and it was pressurized with oil. It was held at

Fig. 14 – Fracture Surface of Test Vessel No. 23. This had been coated inside and outside with primer, and stressed for a total of 2800 min. above 264,000 psi. maximum tangential wall stress. It finally fractured at 318,000 psi. after 45 min. at this level. Initially, the vessel had been pressurized with water, later with oil. Fracture of the vessel was mostly in sheer. There was no discolored area at the origin of fracture, indicating that it had not been hydrogen induced. 10 ×



275,000 psi. for 435 min. Following this, the pressure was increased each hour in steps over a period of 810 min. Failure occurred at 318,000 psi. after 45 min. at this stress level. The fracture surface is shown in Fig. 14. Interestingly enough, the mode of failure through the cylindrical section was largely shear, except for a small tensile progression at the failure origin. There was no evidence of a discolored area at the failure origin, indicating that the failure had not been hydrogen-induced (see Fig. 14). Vessel No. 23 had been tempered in vacuum to reduce the hydrogen content as much as possible. For some unexplained reason, however, hydrogen analysis of the material indicated that it had a level of 9.6 ppm., much higher than any of the other test vessels for which hydrogen analysis was taken, or of the large full-scale missile casing.

That this relatively high hydrogen content in vessel No. 23 did not cause fracture is easily understandable when one considers the role of triaxiality in initiating such failure. The vessel, as any of the other vessels, was carefully made and free of stress concentrations. To initiate fracture, hydrogen must reach a very high level in a local area. This high level is reached in the presence of a stress concentration by the stress-induced diffusion of hydrogen to the area of maximum triaxiality of stress. If there is no such area, then the general level of hydrogen in the material must be very high indeed to bring about delayed failure.

The results of the foregoing delayed failure tests are recapitulated in Fig. 15. Here the average local stress level at the failure origin in each case is plotted against the time to fracture. The local stress level was determined on the basis of the thickness of material at the fracture origin. The vessels had a slightly uneven thickness in the cylindrical portion. The fracture origin in no instance occurred at the thinnest section. It is the maximum tangential stresses at the point of thinnest section that are reported in Table I. Because of this difference the stresses in Fig. 15 are slightly lower than those appearing in Table I. The fact that the fracture origin in the small vessels was usually between 1 and 2 in. from the weld is indicative of secondary bending stresses caused by welding. The actual stress here may therefore be higher than is indicated by Fig. 15. No fracture began in a heat-affected zone.

When this series of tests was completed, two full-size solid-fuel rocket casings, as shown in Fig. 1, were hydrostatically tested with oil. They were cycled four times from zero stress to a tangential stress level of 220,000 psi., being held 3 min. in each cycle. They were then cycled four times to a stress level of 240,000 psi. and again held for 3 min. in each cycle. The vessels retained their integrity and subsequent detailed examination showed no damage.

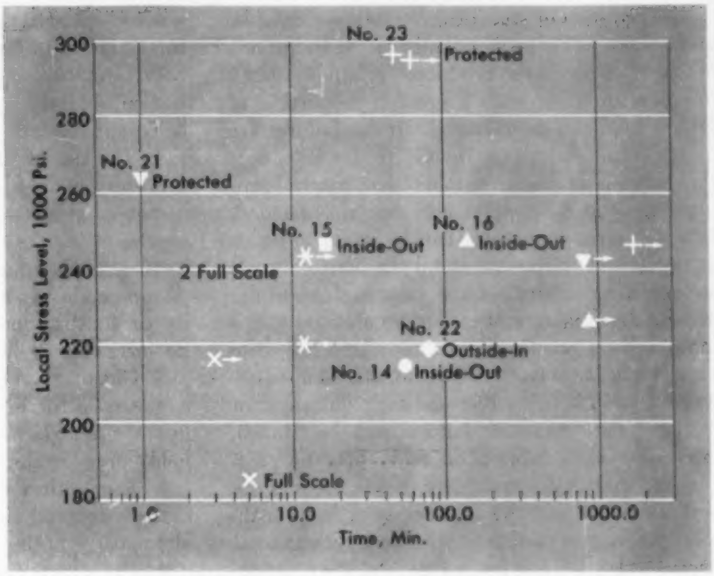
Discussion and Conclusions

In the tests of the full-size and subsize vessels, two facts are clear. First, if a vessel is free of fabrication defects, failure can be induced at high tangential stresses in the parent metal away from weld areas and changes of contour, providing the metal is not allowed to come in contact with an electrolytic solution. This is seen in test vessels No. 21 and 23, protected from electrolytic action. The stress levels at which they failed were higher than any of those in vessels which were exposed to water during testing. Second, it is possible to transfer the origin of the fracture from the inside to the outside surface, as in vessel No. 22, by protecting the inside and exposing the outside to an electrolytic solution, even though it be a weak electrolyte such as tap water. This argument is reinforced by the appearance of the fracture origins. In the vessels exposed to an electrolyte, the origins showed the local darkening typical of hydrogen-induced failures. In the protected vessels, there was no evidence of this.

It is interesting to compare the time required for failure in the large tank with failure times for the smaller, unprotected tanks. In its last series of tests prior to fracture the large tank contained water for 55 min. Of this time, only 6 min. was at stresses above 154,000 psi. The smaller unprotected tanks, however, were under maximum tangential stresses of 200,000 psi. or higher for continuous periods ranging from 113 min. to hundreds of minutes. This would imply that the failure times were in some way affected by the surface area exposed to water, or the volume of water present. An attempt was made to reproduce a hydrogen-induced failure on a simple tensile specimen of H-11 steel submerged in water. To assist matters, a spot at the center of the gage length was ground with a rubber wheel. No fracture occurred, even after several days.

The mechanism of the hydrogen charging is not fully understood. Normally, liberated hydrogen is not driven into steel at room temperature. Perhaps the high stress, in conjunction with some chemical effect originating from the steel itself may be responsible. Another speculation is that the high elastic distortion of the

Fig. 15 – Résumé of Delayed Failure Test Results. The graph shows the local stress level at the origin of failure, plotted against the time to delayed failure. Stress levels here indicated are slightly lower than those shown in Table I because the test vessel never failed at the thinnest section. Repeated use of the same symbol signifies repeated test of the vessel. Arrow signifies vessel did not fail



crystal lattice may promote solution of hydrogen. Further investigation is necessary.

Comparison of maximum tangential stresses at the thinnest section in Table I and the local average stresses at fracture origins in Fig. 15 shows that the failure always originated in an area of lesser average stress, whether or not electrolytic action was involved. It would be extremely difficult, if not impossible, to pinpoint a particular inclusion which triggered the fracture of the protected vessels, No. 21 and 23.

In the instance of protected vessel No. 21, after sustaining 241,000 psi. for 810 min., being depressurized and reloaded to 262,000, it failed in 1 min. Failure accompanied by mechanical delay is possible in non-work hardening materials below the yield point in torsion. In that event, fracture will begin and progress a finite amount from a crack when a critical value of plastic strain is reached. The resulting crack may then stop until the average stress is raised, whereupon it will progress further. When the crack length finally reaches a critical value with respect to the gross structure, failure occurs. The process will take time, and times of the order of seconds to minutes seem about correct.

In the present situation, matters are vastly more complicated. The test vessels are stressed well above the yield point, and the material work hardens. However, a qualitatively similar mechanism can be imagined. Perhaps some inclusion breaks away from the matrix, initiating a stress concentration. There would then be growth of the crack over a short time, followed by gross fracture. If such is actually true, vacuum melted stock is obviously needed for reasons of cleanliness. This is amply supported by the work of Brown and others.* The fact that vessel No. 21 was 4 or 5 points harder on the Rockwell C-scale than it should have been accounts for its lower stress at fracture.

In rocket casings an extremely useful piece of information is the critical crack depth necessary to trigger a failure. The size of the darkened areas in the hydrogen-induced failures of the unprotected vessels indicates the approximate size of such cracks. Figures 11 and 13 show this to be roughly about 0.010 in. This cannot be checked in the protected vessels since there is no difference in texture of the fractured surface between the origin and other areas. However, it seems obvious that, if casing failures are to be prevented, defects of the order of 0.010 in. or larger must be eliminated. This estimate is substantiated by the inset of Fig. 8 (of the previous article) which illustrates a flow-turning defect left in the unrepaired state in the full-size casing. It extends into the vessel wall about 0.006 in. This and others like it played no part in the fracture. They were, of course, surrounded by a deliberately decarburized layer, which undoubtedly helped render them harmless.

*"Preliminary Report on Sharp Notch and Smooth Tensile Characteristics for a Number of Ultra-High-Strength Steel Sheet Alloys", by G. B. Espey, M. H. Jones and W. F. Brown, Jr., A.S.T.M. Preprint, 1959.

The problem of statistical reliability should be mentioned. This is continually raised by makers of tanks who have produced relatively large numbers of them with a greater proportion of failure than can be tolerated. If the failures are of the type described by G. R. Irwin*, it is the opinion of these authors that marked improvement in fabrication and design is needed. When failures repeatedly can be made to occur in test vessels in parent metal (without galvanic action), the statistics become meaningful. In the present investigation, it cannot be claimed that a sample of six subsize vessels and three full-scale vessels is a large one. However, the sample becomes meaningful when in each instance of fracture the cause of failure can be traced, especially when fabrication flaws play no part.

Based on the evidence here presented, it is the authors' belief that the fabrication of large-scale solid-fuel rocket casings to operate at a tangential stress level of 240,000 psi. is practical and feasible. Stress levels above this value appear to be possible, perhaps approaching 260,000 psi. if plastic strains of the order of 1.5% can be tolerated. The question is an open one.

Finally, a word must be said about design philosophy. Obviously, careful attention to details of design, fabrication and choice of material is important. With critical crack lengths of 0.010 in., no detail is unimportant. One must employ such practices as making bosses and skirts integral with the main members of the missile casing and eliminating longitudinal seam welds. Admittedly, these measures are expensive; they do, however, insure integrity in service.

A most important consideration of design philosophy concerns the "notch strength ratio". This has been defined as the ratio of the strength of a sharply notched sheet tensile specimen to the strength of a smooth specimen. Data from Brown show that the tensile strength of a smooth specimen is increased by lowering the tempering temperature. However, the strength of a sharply notched specimen similarly heat treated first increases as the tempering temperature is lowered. Then it decreases. It would be desirable to use only sheet alloys which had a notch strength ratio greater than 1.0. If, however, sufficient care is used in design and fabrication (including elimination of defects greater than the critical crack length), it seems reasonable that alloys can be used which have been hardened to a strength level which will result in a notch strength ratio of less than one. This was the situation in the present vessels. With alloys now available, high operating stress levels will not be obtained any other way.

*Notes for meeting of ASTM Committee, New York, March 24, 1959.

To summarize:

1. The use of water for hydrostatic testing of solid-fuel rocket casings can cause premature hydrogen-induced failures in parent metal by electrolytic action. The exact mechanism of the hydrogen charging needs further study. This phenomenon becomes important when the quality of construction is high so that failure does not originate in fabrication or design defects.

2. Cleanest vacuum melted steel available is a necessity for high-performance casings. Deliberate decarburization to a depth of 0.005 in. helps prevent surface cracks from spreading.

3. The critical crack length in H-11 vacuum melted material heat treated to 270,000 psi. is about 0.010 in. in the stress range of interest.

4. The manufacture of solid-fuel rocket casings to operate at 240,000 psi. is practical and feasible. Stress levels above this value appear possible, perhaps to 260,000 psi. if plastic strains of the order of 1.5% can be tolerated. This requires further investigation.

5. With present alloys, it is necessary to design to notch strength ratios of less than 1.0 to secure minimum feasible weight. This requires best quality in design, fabrication and materials.

Finally, it should be noted that philosophy of design and construction in the missile field, particularly with solid-fuel rocket chambers, has been obscured in the past because missiles are single application structures. It has been presumed that the structure only had to last through one application and it was not very sensible to spend more than the minimum time necessary to fabricate it. It has become apparent, however, that if any solid-fuel rocket chamber is to be made well enough to preserve its integrity through one or a few stress applications, it must be designed and constructed well enough to last through many stress applications and for much longer periods of time than it will be stressed in service. If it cannot do this, it will not work at all. This is not a new realization. It has been known in the aircraft propulsion field for many years and has been the philosophy used in the manufacture of turbojet engines. If missile casings are to operate in a satisfactory manner, then in view of the extremely high stress levels that are necessary and the rewards for obtaining these stress levels, even higher standards of quality are in order.

*Aircraft Nuclear Propulsion**

A project to study the feasibility of nuclear-powered aircraft (NEPA) was authorized by the Air Force in May of 1946; the contractor was Fairchild Engine & Airframe Co., and work was started at Oak Ridge. By the end of 1948, the Air Force had invested about $10 million in the project, and the so-called Lexington report, prepared by Massachusetts Institute of Technology, predicted that nuclear-powered flight could be achieved in about 15 years. At the end of 1949 the Atomic Energy Commission became an active partner and in February 1951 the two sponsors agreed on the general feasibility of the project, closed NEPA and started the ANP (Aircraft Nuclear Propulsion) project to "develop a strategic weapons system which would eliminate the limitations of conventional power plants as to range and endurance". General Electric Co. at Evendale, Cincinnati, was named as contractor to develop a direct-cycle turbojet power plant, wherein the propulsive air is heated directly by drawing it through the reactor core. In September 1955, Pratt & Whitney Aircraft Div. of United Aircraft Corp. was authorized to study an indirect cycle (where heat is transferred from reactor core to propellant gas by an intermediate fluid, liquid or gas) and Connecticut Aircraft Nuclear Engine Laboratory (CANEL) started work.

Meanwhile the "flying test bed" program was canceled (May 1953) and efforts turned toward a series of high-temperature reactor experiments, which led the A.E.C. in 1955 to report "progress exceeding expectations". In 1956 two reactors were successfully tested at the National Reactor Testing Station in Idaho. Seemingly, however, these results were not sufficiently superior to what might be expected from conventional fuels to convince the military sponsors that work should be expedited so to achieve early flight.

*Summarized from Report of the Congressional Joint Committee on Atomic Energy, dated September 1959, entitled "Aircraft Nuclear Propulsion Program".

Total expenditures to the end of fiscal 1959 are close to $850 million, with about $150 million more anticipated for fiscal 1960.

Little has been said publicly about this program. The A.E.C.'s semiannual reports are confined to a few short lines. The Congressional Joint Committee has held 36 closed meetings on the program during the last 11 years. The present report summarizes evidence presented in the first public session July 23, 1959 and says: "Over the years the ANP program has been handicapped by changes in policy and lack of objectives. While technical objectives have been generally met by the contractors, there are apparently no firm military requirements set by the Joint Chiefs of Staff at present." General Thomas White, Air Force Chief of Staff, said that there will be need for manned vehicles "for the foreseeable future . . . and that vital military applications will derive from nuclear propulsion".

The general objectives of the present program were stated by Herbert York, director of defense research and engineering, thus: (*a*) Study only those power plants which would be useful for military flight; (*b*) evaluate the indirect cycle power plant as soon as possible; and (*c*) defer a specific flight program until a power plant is established as feasible and potentially useful and when such a program will not seriously interfere with further improvements.

There has been a pronounced difference of opinion as to the desirability of "early flight" as a useful step in developing a more sophisticated aircraft, for its propaganda effects, and to hearten the men engaged in the project. The Congressional committee is in favor of early flight, as is Maj. Gen. Donald Keirn, present director of ANP, who believes many important problems of flight can be solved thereby without delaying the installation of improved reactor cores. The A.E.C.'s General Advisory Committee is also of the opinion that the direct cycle propulsion system, as now existing, can be used to propel a military aircraft.

On the other hand, Thomas Gates, Deputy Secretary for Defense, believes that propulsion systems made of our present materials "will fall far short of chemically fueled competitors" and would have little chance for future improvement. Proponents of early flight claim that it would not interfere with a search for better materials of construction — quite the contrary. Dr. York said, however, that changing a reactor core in an airship "is not a minor thing". Secretary Gates adds that the proper time to fly an airframe would be "when we have a reactor that is possible of greater growth than the reactor we would now have to use". A further point of difference concerns the first test flight vehicle or "test bed". In the past it was felt that this might merely be a modified existing airplane, like the B-36, a tanker plane, or a British "Princess" flying boat (which the Navy could use as a submarine hunter). General Keirn now believes that a new airplane should be specifically designed for nuclear propulsion. This would require several years to design and build.

In brief summary, the Joint Congressional Committee notes that neither the Department of Defense nor the Joint Chiefs of Staff have set any general operating requirement for a nuclear-propelled military aircraft, and suggests that Congress might therefore take the matter away from the soldiers and sailors and place primary responsibility on the Atomic Energy Commission to develop "a ground test prototype propulsion system, and flight test it in an experimental aircraft. . . . This would provide the basis for a judgment by the defense department on firm military requirements." The Atomic Energy Commission on October 9 said that General Electric's program (direct cycle engine) has been revised so as to place "increased emphasis on advanced fuel elements" of great promise. "The goal of the re-oriented program is a militarily useful propulsion system of high performance and long life."

Light Metallurgy

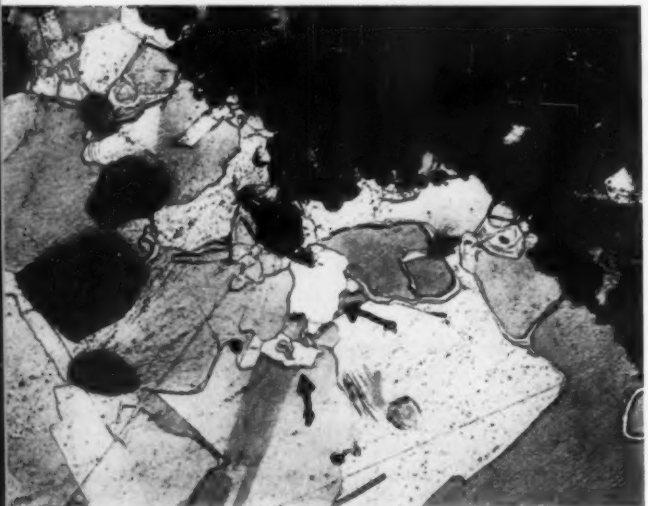
A Short Tour of Archeological Metallurgy

*By DAVID J. MACK**

Determining the true source of a questionable prehistoric artifact of metal is no easy task. Some of the problems met and solved (sometimes) in examining Indian copper bells, a "Viking" halberd, and two dubious candelabra are discussed in this article. (A2; Cu-b)

THE FIRST GENERATION of primitive physical metallurgists was quite happy to apply the shiny new tool of metallography to archeological problems. These pioneers cheerfully worked on and wrote about such diverse subjects as Damascus steel, medieval armor, Bronze Age casting techniques, and the manufacture of ancient Egyptian wire. The English and the Germans seemed the most curious about ancient metallurgy, perhaps because of their wide training, and the many archeologists and museum collections in both countries. In this country archeological work was less common, probably because American metallurgists had less to work with. Our Indians were much more limited, metallurgically speaking, than the Egyptians, Greeks, and Romans of classical antiquity.

Fig. 1 – Grains of Pure Silver in Native Copper From Upper Michigan. Many of the copper grains appear to have double boundaries of a type associated with grain growth. Etched in bichromate; 100 ×



With the passing of the pioneer physical metallurgists, papers on archeological metallurgy by metallurgists appeared only sporadically. Work that had to be done was done ably by the archeologists themselves, though probably with considerably more "blood, sweat and tears" than a professional metallurgist would have had. Lately, however, scientific archeology has grown, and the practicing metallurgist again happily finds himself in a position to contribute substantially to archeology.

American metallurgists who deal in archeological problems are faced with unique difficulties. The main one, probably, is lack of data; American aborigines were notoriously lax in recording the numerous facts and figures that we find so helpful in analyzing industrial problems. However, since they had no written language, they must be forgiven for this oversight. Within

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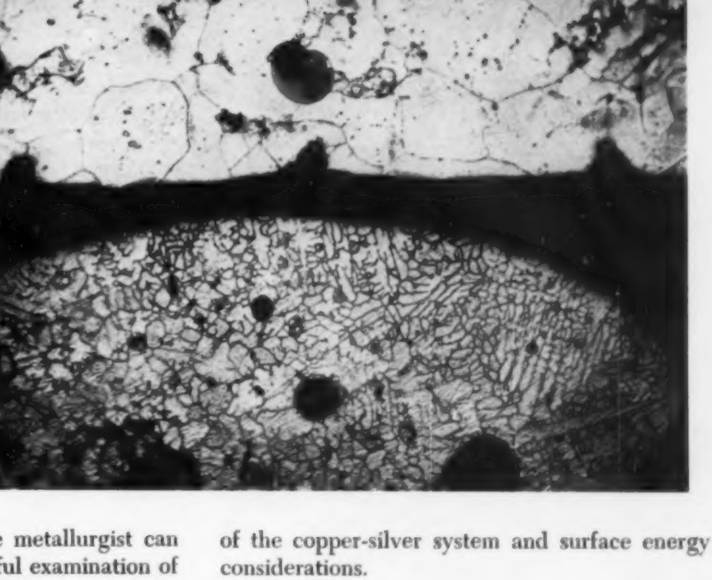
Fig. 2 – Grooves on Surface of Cast Bell. The grooves appear along the bottom edge of this cross section (top). Compare this section with the modern tough pitch electrolytic copper containing 0.02% oxygen shown below. Etched in bichromate; 50 ×



these limitations, however, the metallurgist can often discover much from careful examination of artifacts. As examples, consider the following experiences:

Items Made From Copper

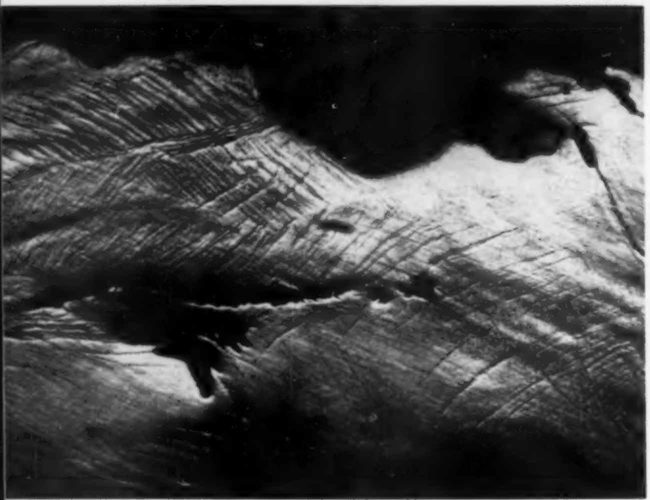
Several years ago, one of my students, to settle a bet with a graduate student in archeology, obtained several copper artifacts (with permission, of course) from the Wisconsin State Historical Society. They included a copper chisel, copper axe, and a copper spud. He examined them to determine whether they had been cast or wrought. A single glance showed that they had been fabricated from native copper by working (whether hot, or cold plus anneals, or by a combination was impossible to establish). Curiously, the last operation was a recrystallizing anneal; this eliminated all the beneficial hardening effects that cold working may have imparted.

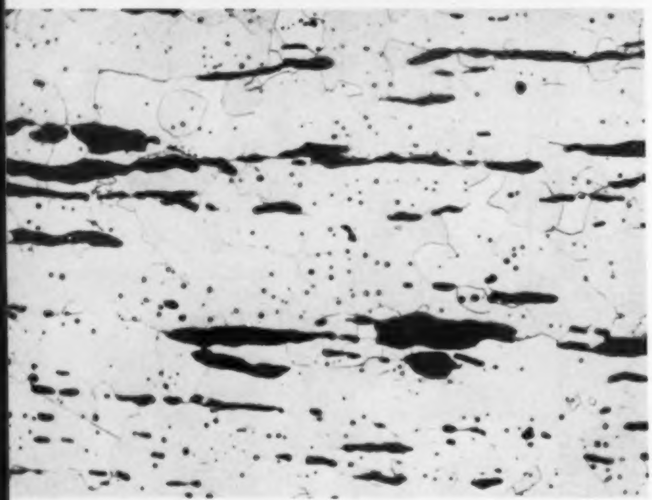
The interesting structure of these items led to an extensive investigation into the microstructure of native copper. Among other things, we found that the structure of native copper mined in Upper Michigan occasionally contains small inclusions of pure silver (Fig. 1). The writer has seen this silver coming off the wilfley tables in a discrete stream separate from the copper, but had always assumed the silver to be held in the rock matrix and not in the copper as well. This intimate association of copper and silver poses interesting questions for the geologist as well as the metallurgist concerning the phase equilibria of the copper-silver system and surface energy considerations.

Cast Copper Bells

One of our first investigations concerned small copper bells frequently found in the Southwest. Previous work by others led to the belief that these prehistoric bells were cast, probably centrifugally, by the lost-wax process. We examined a bell from the collections of the Arizona State

Fig. 3 – Inclusions in the Cast Bell. These could be a clue in identifying the source of the copper. Unetched; 500 ×





Museum, first removing the heavy patination by a weak macro-etch. An unexpected set of lines appeared on the surface, evenly spaced and parallel to the mouth of the bell. The question then arose: "Were these lines engraved or incised, or did they result from the wax pattern?" Examination of the cross-section of the bell (Fig. 2) answered the question immediately. Obviously, the lines were formed during the casting process, and are probably due to wax threads used in making the wax pattern. The extremely thin sections (0.01 in. in certain parts of these small bells) and the hollow handles seem to prove that the bells could only have been made by centrifugal casting, or by forcing the molten metal into the mold cavity by gas pressure. This entire technique is probably an ancient one with the Mexican Indians.

Another question always foremost in the archeologist's mind is: "Where did the copper come from?" In the Southwest, there is a small amount of native copper, as well as large amounts of both oxide and sulphide ores. Thus, the copper in the bells might be remelted native copper (unlikely because of the high temperature needed) or smelted ore. Figure 3 shows the inclusions in the copper. Can the source be identified from them? Perhaps someone familiar with the microstructure of cast coppers can answer the question.

Another type of copper ornament encountered in the Southwest is the "tinkler", a small hollow cone of metal. When examining one of these from Chihuahua, the writer observed the structure shown in Fig. 4 and 5. Figure 4 is the unetched structure; from its cleanliness it can only be native copper. The extensive working which the copper received in making the tinkler is shown in Fig. 5. Obviously, this extensive cold working indicates that the piece of native copper was hammered flat before being formed into the tinkler.

Vikings in Minnesota – A resident of Wisconsin or Minnesota cannot help knowing about the

Fig. 4 – Native Copper in the "Tinkler" Was Free of Inclusions. Etching was needed to reveal strain markings. Etched in bichromate; 500 ×

Fig. 5 – Cross Section of Tinkler Heavily Etched to Show Strain Markings. Etched in bichromate; 50 ×

Fig. 6 – Section of Halberd Tang. This is obviously wrought iron, a material whose softness limits its usefulness in cutting implements. Etched in 2% nital; 250 ×

Machining Ultra-High-Strength Alloys

Source: Metcut Research Associates, Inc.

Alloy and Hardness (a)	Tool (b)	Tool Geometry (c)	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-Land (d)	Cutting Fluid
		Turning – Carbide Tools. Cutter: ½-In. Square Throwaway Holder With Mechanical Chip Breaker							
A.I.S.I. 4340; C-52	C-8	SR: −5°; SCEA: 15°; BR: −5°; ECEA: 15°; Relief: 5°	0.100 in.	—	0.009 in./rev.	150 ft./min. 300	47 min. 10	0.016 in.	None
VascoJet 1000; C-52	C-8	SR: −5°; SCEA: 15°; BR: −5°; ECEA: 15°; Relief: 5°	0.100	—	0.009	100 200	50 10	0.016	None
AM-350	C-2	SR: 5°; SCEA: 15°; BR: 0°; ECEA: 15°; Relief: 5°	0.100	—	0.009	150 200	60 5	0.016	None
A-286	C-2	SR: −5°; SCEA: 15°; BR: −5°; ECEA: 15°; Relief: 5°	0.100	—	0.009	150 250	25 7	0.016	None
		Face Milling – Carbide Tools. Cutter: 5-In. Diam., 5-Tooth Inserted-Tooth Face Mill							
A.I.S.I. 4340; C-52	C-6	AR: 0°; ECEA: 5°; RR: −15°; Cl: 8°; CA: 45°	0.100	2 in.	0.005 in./tooth	150 225	330 in. 180	0.016	None
VascoJet 1000; C-52	C-2	AR: 0°; ECEA: 5°; RR: −15°; Cl: 8°; CA: 45°	0.100	2	0.005	125 175	400 100	0.016	None
		Side Milling – Carbide Tools. Cutter: 7-In. Diam., 6-Tooth Inserted-Tooth Face Mill							
A.I.S.I. 4340; C-52	C-6	AR: −5°; ECEA: 5°; BR: −10°; Cl: 8°; CA: 45°	0.100	1¾	0.0075	150 220	380 75	0.016	None
VascoJet 1000; C-52	C-2	AR: 0°; ECEA: 5°; RR: −15°; Cl: 8°; CA: 45°	0.100	1¾	0.0075	150 260	390 90	0.012	None
		End Milling – High Speed Steel Tools. Cutter: ¾-In. Diam., 4-Flute End Mill							
A.I.S.I. 4340; C-49	T-15	35° RH helix; CA: 45° × 0.060 in.; Per. Cl: 6°	0.250	¾	0.001	55 80	70 30	0.016	Soluble oil flood (20:1)
		End Milling – Carbide Tools. Cutter 1¼-In. Diam., 4-Flute Brazed-Tip End Mill							
A.I.S.I. 4340; C-52	C-2	AR: 0°; ECEA: 3°; RR: 0°; Cl: 15°; CA: 45° × 0.030 in.	0.250	1¼	0.0015	50 80	78 40	0.016	Chemical emulsion (e) (40:1)
VascoJet 1000; C-52	C-2	AR: 0°; ECEA: 3°; RR: 0°; Cl: 15°; CA: 45° × 0.030 in.	0.250	1¼	0.0015	60 150	105 55	0.016	Soluble oil (e) (20:1)

(a) VascoJet 1000 and 4340 are quenched and tempered; A-286 and AM-350 are solution treated and aged.
(b) C-2, C-6, and C-8 are carbides; T-15 is a tungsten-base, high speed toolsteel, and M-10 is a molybdenum-base, high speed toolsteel.
(c) AR = axial rake; RR = radial rake; CA = corner angle; SR = side rake; BR = back rake; SCEA = side-cutting edge angle; ECEA = end-cutting edge angle; Cl = clearance.
(d) Wear on the peripheral flank of the cutter.
(e) Applied as spray mist through axis of cutter.

600° to 1000° F.

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controversial Kensington Stone. This stone, unearthed in Minnesota in 1898 and covered with runic characters, purports to describe the fate of a band of Vikings at the hands of Indians in that area about 1362 A.D. Naturally, metallurgists should be curious about the iron weapons carried by these Vikings. Some which appear authentic have turned up and have been exhaustively described. However, we know of no metallurgical examination that has even been made of these weapons. Recently one of them, a halberd, was presented to the Wisconsin State Historical Society, and the writer examined small sections metallographically.

Small pieces, removed from the cutting edge of the blade and from the tang, proved that the material was hand-puddled wrought iron of good grade (Fig. 6). Although the blade of the halberd had been corroded, there was no trace of any hardening on the cutting edge.

Heavier etching also revealed Neumann bands near the cutting edge. It gives one a vicarious thrill to speculate that these Neumann bands might have been formed as the Viking chopped into his enemy's bones or armor. This lack of a hardened edge also points up what has long been known about many other Viking weapons. Vikings depended more upon sheer strength to batter their opponents into submission than upon any finesse or technique with sharp weapons.*

*Although the preponderance of evidence seems to indicate that the Kensington stone is a hoax, this still does not explain the finds of ancient-type iron weapons in the Minnesota-Wisconsin area. These weapons are identical with similar specimens of known age in Scandinavian museums. If it's all a hoax, how did the weapons get there?

The obvious explanation is that they were brought by Scandinavian immigrants as family keepsakes and then lost. (This seems improbable.) Another story that particularly applies to the halberd in question is that they were widely used in the '80's, '90's and early 1900's to advertise various brands of tobacco such as "Knight", "Viking", "Red Man", and so on. This is probable for the halberd, swords and axes that have been found, but I fail to see how it would apply to the massive crunching weapons, used to bust up an opponent's bones and armor. They certainly would not have enough eye appeal to act as advertising media. The whole question is still up in the air.

Fig. 7 – This Candelabrum Was Assembled by the Author. Though much was discovered during subsequent work, its true antiquity could not be proven

Such an examination settles no questions – authenticity of the halberd, age or origin. In passing, it was originally hoped that the material would be high enough in carbon to establish a radio-carbon date.

The Candelabra in the Junk Shop

Far more puzzling in origin than the weapons is a pair of candelabra brought to the writer's attention by one of his friends who is a junk-shop haunter. One of these is shown in Fig. 7. Knowing that the writer is a metallurgist as well as a frustrated mechanic, this friend asked if the candelabra, which had been broken in several places, could be reassembled. The blithe answer was, "Certainly"! Closer inspection, prior to reassembly, revealed that the candelabra had not been "broken" in the usual sense, but had come apart at pinned and leaded joints. While they appeared crudely made, considerable ability was needed in designing the parts. Assembling them also required much skill.

It was soon obvious why the candelabrum had been assembled from a number of smaller castings. The pattern was extremely intricate. With its reverse curvatures of surfaces and reentrant angles, the pattern could not have been withdrawn from the mold. (However, it would have been ideal for casting by the lost-wax process.) Since the candelabra burned oil, and had ancient design motifs such as a winged lion with human head and the stylized lotus or acanthus leaves, it was suggested that they might be a collector's item. (Of course, they could have been fakes, too.)

Anyway, the writer dashed off, candelabra in hand to one of his colleagues in the Classics Department who considers himself primarily a historian but has done considerable archeological work in Italy. He believed he had seen some similar ones someplace, perhaps in archeological material from Pompeii. At his suggestion, a magnificent work containing extensive photographs of Pompeiian treasures was consulted. Behold! Several candelabra shown seemed nearly identi-

cal to the ones we had in hand. However, while such evidence is helpful, it is inconclusive. It only serves to whet one's appetite to establish the authenticity.

Not long afterward the writer spent a week in Chicago, accompanied by a candelabrum as well as a wife and some friends who also have an armchair interest in archeology. In the time available, no one consulted was able to help identify the oil lamps – antique dealers, the Field Museum, the Chicago Art Institute, or the Oriental Institute at the University of Chicago. One of the men at the Oriental Institute suggested an elementary test; if they were a copper-tin bronze, they might be ancient; if they were a copper-zinc alloy, they were probably no older than the 15th or 16th centuries A.D., assuming the candelabra were genuine.

Subsequent metallographic examination showed the candelabra to be cast alpha brass with about 3% lead, similar to leaded yellow brass, a modern material widely used for intricate castings. According to the simple rule suggested at the Oriental Institute, this clearly made the candelabra Renaissance or later.

However, this was not the final answer. Further search of the metallurgical literature revealed that this same brass was used by the Romans as early as 20 B.C., ". . . not only for coinage but also for fibulae, personal ornaments and decorative metal work". It was also found that component parts of large cast objects were often assembled with pins, usually wrought iron. Joints were then filled with lead.

Examination of several of the pins from the candelabra showed them to be of the same leaded yellow brass, each one being crudely threaded at both ends. One pin showed what appeared to be machining marks on its end. In addition, there were faint grinding marks on the bottom of the feet which, from their regularity and uniformity, must have been made by modern machine grinding methods.

So the problem remains unanswered – are the candelabra ancient and of considerable archeological and historic interest, are they clever forgeries, or are they Victorian junk, similar to the statues with belly clocks? The composition of the brass, the technique of assembly, the design motifs, and the fact that they are oil lamps argue for their authenticity. Against this are the threaded brass pins and the machining marks.

This brief excursion into romantic metallurgy with the Viking halberd and the candelabra points up the limitation of physical science in attempting to authenticate archeological artifacts. We can usually certify compositions, methods and techniques of manufacture. But when one is dealing with an artifact of unknown origin, it is the cultural principles, the design and its execution on the artifact as compared to known types that will establish the authen icity, once the physical evidence is favorable.

While these few examples of metallurgical archeology may seem elementary to the metallurgist, the results are interesting because they provide us with information about the background of our chosen field. While our ancestors may not have appreciated some of the simplest metallurgical facts of life, there is also ample evidence of experiment and techniques of a very high order.

You, Too, Can Be a Metallurgical Archeologist

Many metallurgical and related techniques are useful to the metallurgist who acquires a leisure-time interest in archeological or historical metallurgy. For example, the archeologist sometimes wonders whether a particular iron artifact was made of meteoric iron or from smelted ore. A simple spot test will tell him at once because meteoric iron is fairly high in nickel. Tracing Indian trade routes in North America is another common problem. Important here is the origin of the metallic articles as to geologic site. Spectrographic analysis is often helpful. For example, the native copper deposits in upper Michigan are unique in that they do not contain even spectrographic traces of gold. One afternoon per month with a quantometer would pinpoint the origins of many artifacts.

Macro-etching techniques have probably not been as extensively used on metallic artifacts as they should be, particularly where the patination is heavy. Carefully applied macro-etches reveal unsuspected surface detail, and are very useful for separating copper, brass and bronze artifacts or fragments. Looking to the future, it is certain that metallurgical techniques as useful as radiocarbon dating will be developed. It is not illogical to suppose that studies of the decay of the relaxation spectrum of cold worked materials will provide for more precise timing of the era during which a particular artifact was fabricated.

In conclusion, archeological and historical metallurgy, although they can rightly be regarded as a busman's holiday for the professional metallurgist, are fun. And you can't beat fun.

Sodium Bisulphite as an Etchant for Steel

By J. R. VILELLA and W. F. KINDLE*

Sodium bisulphite improves the contrast of the microconstituents in steel without selectively overetching fine structures such as pearlite and bainite. (M20q; ST)

THE USE OF AQUEOUS SOLUTIONS of sodium bisulphite ($NaHSO_3$) as a metallographic etchant for steel and cast iron was first described by L. Beaujard and Mlle. J. Tordeux†. According to these investigators, best results are obtained by etching with a 21 to 28% aqueous solution at room temperature for 10 to 25 sec. Etching effects produced by this reagent are essentially the same as those obtained by heat tinting at higher temperatures. Specifically, some of the merits claimed for this etchant are: (*a*) It enhances contrast between adjacent ferrite grains in low-carbon steels; (*b*) it defines austenite grains, martensite and undissolved carbides in quenched high-carbon steels; (*c*) it is superior to saturated picral in revealing lines of deformation and other fine details of the structure of broken test specimens; (*d*) it is highly sensitive to chemical segregations; and (*e*) it brings out clearly the carbide network in carburizing tests.

The etching properties of sodium bisulphite were further studied by B. V. Guellard‡, who corroborated the claims made by the French investigators. In addition, he found that, when applied to low-alloy, high-strength steels, sodium bisulphite tints the grains three different colors which are reproduced as three distinct shades of gray when the steel is photographed in black and white. Like Stead's reagent, sodium bisulphite reveals phosphorus segregation, which 5% nital fails to do, and brings out at the grain boundaries of cold reduced rimmed steel certain white bands, slightly raised from the surface, which disappear on normalizing. According to Guellard, this demonstrates the suitability of the reagent for revealing chemical segregations and possible lattice distortion at the grain boundaries. He also found that when applied to cast iron, sodium bisulphite contrasts carbides and phosphides better than Stead's reagent or nital.

Another quite remarkable and useful property of this reagent, not discussed either by Beaujard and Tordeaux or by Guellard, is its ability to etch

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†*Revue de Metallurgie*, Vol. 52, September 1955, p. 750; *Revue de Metallurgie* Vol. 49, January 1952, p. 394.

‡*Metallurgia*, Vol. 54, No. 332, August 1956, p. 93.

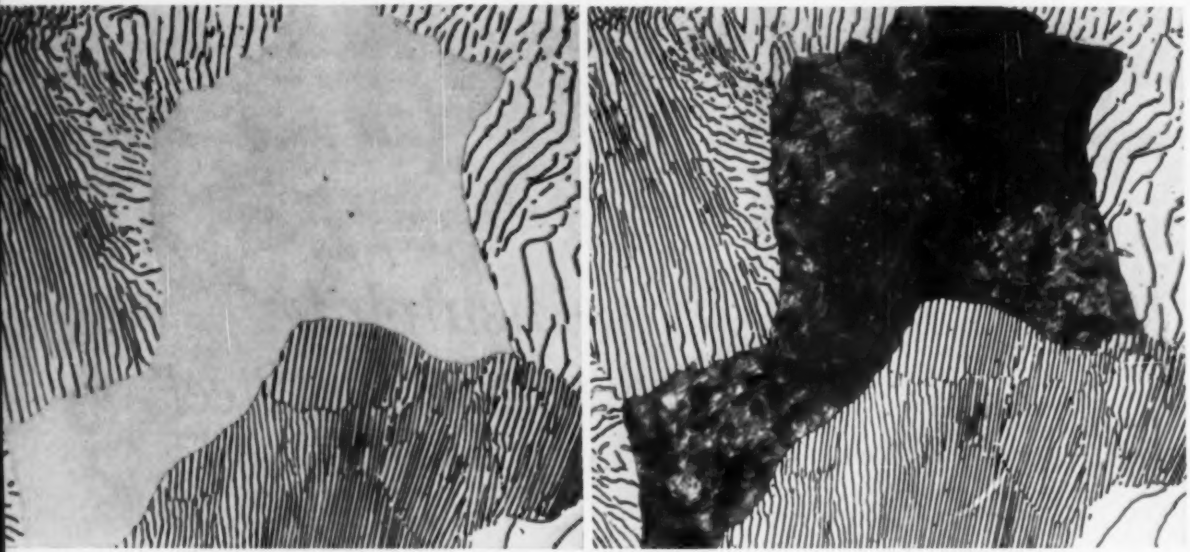


Fig. 1 – Photomicrographs of a Plain Carbon Eutectoid Steel Show That Sodium Bisulphite Etches Martensite and Pearlite at the Same Rate. (Left) Etched 15 sec. with picral; (right) etched 10 sec. with sodium bisulphite. Both 1000 ×

or darken untempered martensite* at least as fast as it etches practically all other microstructures of steel, including some tempered martensites. In Fig. 1, which shows microstructures of a plain carbon eutectoid steel, the rate of etching of pearlite and martensite in sodium bisulphite is contrasted with the rate of etching in saturated picral. In structures consisting of fast-etching fine nodular pearlite and upper bainite in a martensite matrix, sodium bisulphite brings out the needle structure of martensite without over-etching the fine pearlite or bainite.

Isothermal Transformation Studies

This reagent can also be used as shown in Fig. 2. The structure was produced in a steel containing 0.18% C, 0.67% Mn and 1.07% Ni, by partial isothermal transformation at 1050° F. It consists of dark areas of what may be called fine pearlite, and comparatively large needles of Widmanstätten ferrite in a matrix of martensite. The etching problem presented by this type of structure is that, while conventional etchants produce sufficient contrast to differentiate ferrite from martensite, they also invariably blacken the fine pearlite, thereby obliterating all details in the structure. This can be avoided by first etching lightly with saturated picral (Fig. 2, left) and then superimposing a light etch with sodium bisulphite (Fig. 2, right) which confines its action mainly to the martensitic matrix.

Sodium bisulphite is useful in the study of isothermal transformation of low-carbon steels. The technique consists of etching with picral followed by 1% nital and sodium bisulphite. It clearly defines the various transformation products found in such steels, and is helpful in distinguishing ferrite from low-carbon martensite.

Etchant Composition

Because aqueous solutions often do not wet highly polished metallic surfaces evenly, it is advantageous to add one drop of 25% Aerosol or other equivalent wetting agent to every 100 cc. of solution. Good polishing technique is necessary when etching with sodium bisulphite because the reagent brings out fine scratches not visible after etching with picral or nital solutions.

The concentration of sodium bisulphite in solution is not critical for the purpose of darkening martensite. Good results have been obtained with concentrations ranging from 10 to 35%.

Aqueous solutions of potassium metabisulphite and of ammonium persulphate will also etch steel, but they do not appear to possess any advantage over sodium bisulphite.

*The phrase "untempered martensite" as used here refers to martensite which has not been tempered deliberately. Martensite in the examples shown has been slightly tempered (probably 1 or 2 min. above 300° F.) as a result of mounting the specimen in bakelite for metallographic polishing.

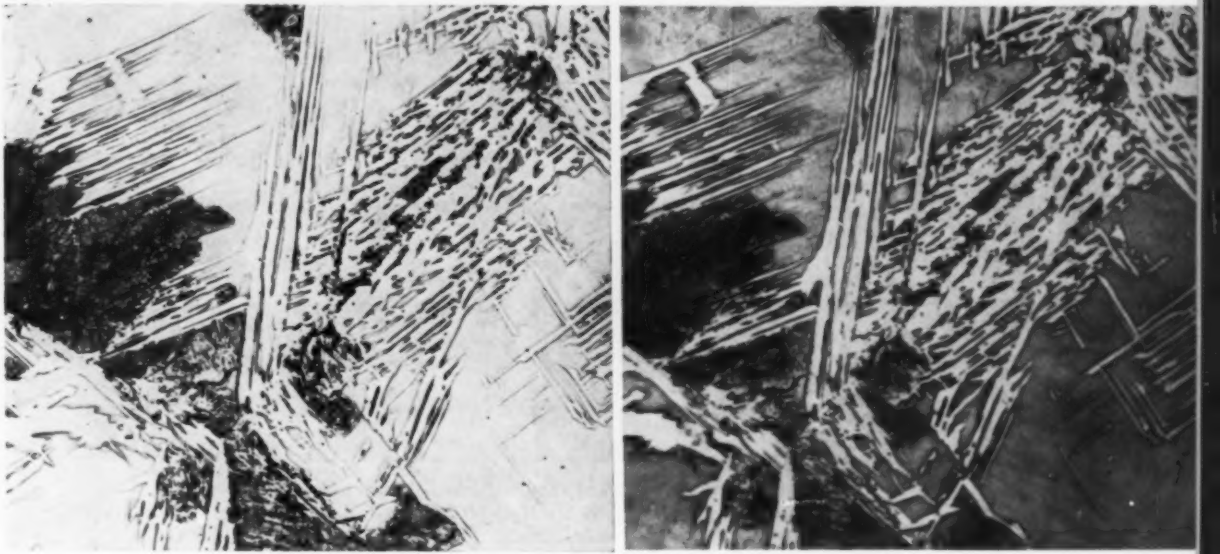


Fig. 2 — Sodium Bisulphite Applied After a Light Picral Etch Provides Good Contrast Between Martensite and Ferrite Without Attacking Excessively the Fine Pearlitic Structure. (Left) Etched with picral alone; (right) with a light sodium bisulphite etch superimposed. 1000 ×

New Techniques for Etching

Etching Uranium for Bright-Field Examination

*By W. N. POSEY**

A new chemical etchant permits micro-examination of uranium under bright-field illumination. (M20q; U)

A CHEMICAL ETCHANT has been developed that will reveal the grain structure of uranium under bright-field illumination. Such an etchant is desirable because of the disadvantages in routine micro-examination of uranium by polarized light. For example, as the specimen is rotated, the grains seem to assume different sizes. Of course, bright-field examination of uranium is possible if the metal has been prepared by cathodic vacuum etching, but the chemical etching technique is much simpler, faster and more amenable to routine use.

The etchant is composed of 130 ml. H_2SO_4 (concentrated), 50 ml. H_2O_2 (30 wt.%), 0.2 g. Na_2SiF_6, and 60 ml. water. The specimen should be immersed in the etchant immediately after

*Chemist, Savannah River Laboratory, E. I. du Pont de Nemours & Co., Aiken, S.C. This article was developed from work under contract AT (07-2)-1 with the U.S. Atomic Energy Commission.

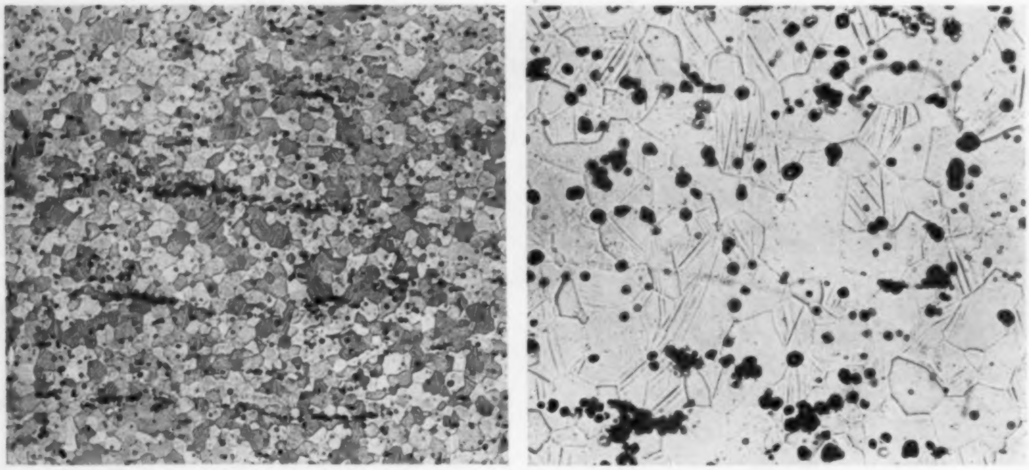


Fig. 1 – As-Rolled Alpha Uranium Etched With a Solution Containing 130 Ml. H_2SO_4, 50 Ml. H_2O_2, 0.2 G. Na_2SiF_6, and 60 Ml. Water. Left, 50 ×, right, 250 ×; both under direct lighting

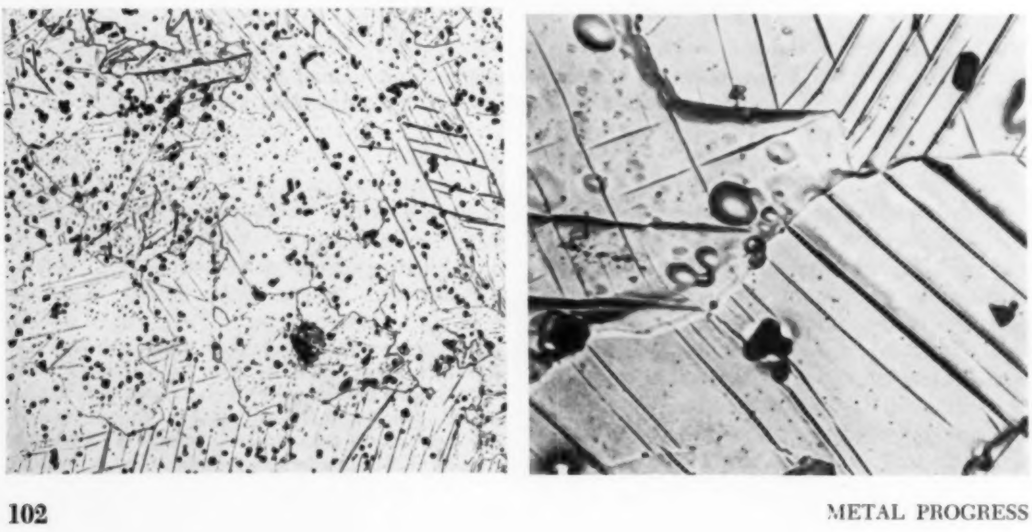
the H_2SO_4 is added. Etching time is approximately 30 sec. Because of the highly exothermic reaction between H_2SO_4 and H_2O_2, the solution rises to about 285° F. and boils for about 3 min. after the H_2SO_4 is added. After this 3-min. period, the solution will attack the uranium to some extent, but will not etch it satisfactorily. The Na_2SiF_6 forms a complex with the free uranium ions, thereby preventing the formation of salt crystals on the surface of the specimen.

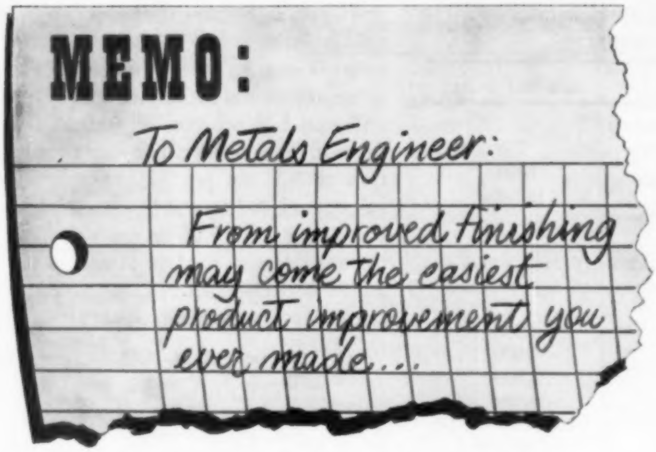
Although satisfactory etching can be obtained over a wide range of grain sizes with the recommended etchant composition, the water content should be reduced by about 25 ml. when etching specimens have very small grains. Reducing the water content results in less pitting on the small grains, which appear to etch at a slightly slower rate than large grains.

During etching, a thin oxide film forms on the specimen. It is removed by electropolishing with the same electrolyte and conditions normally recommended for uranium.

Figures 1 and 2 show photomicrographs typical of those obtained from as-rolled and beta-transformed uranium which have been chemically etched.

Fig. 2 – Beta-Transformed Uranium. Same etchant as Fig. 1. Left, 75 ×, direct lighting; right, 500 ×, slightly oblique lighting





No. 3 in a Series on Better Finishing

Alkaline Cleaning of Metals
Part II—Selecting Equipment, Maintenance Requirements and Costs

*By the A.S.M. Metals Handbook Committee on Alkaline Cleaning**

The first part of this article, published in last month's *Metal Progress*, described methods, cycles, and cleaner formulations for soak, spray and electrolytic cleaning. This section considers equipment requirements, maintenance schedules, and operating costs. (L12k, 1-52, 17-53)

ALKALINE CLEANERS are weakened by reactions with acid soils and hard water, sludge due to common ion adsorption on solid soils or emulsified oils, and by dilution resulting from water additions made to replenish dragout losses. Periodic tests should be made as a basis for controlling the solution strength.

Check Concentration

The preferred practice in maintaining the strength of the process is to make small additions of the compound at regular intervals, and to establish the operating strength of the cleaner as a range. Control for installations that clean large quantities of material (over 10,000 sq.ft. per hr.) requires the solution to be titrated every 1 or 2 hr. Titration every 4 hr. is usually sufficient for smaller quantities. After the titration, a pattern of cleaner addition is developed con-

*Members of the committee are Braly S. Myers (chairman), Walter L. Acker, A. R. Balden, J. M. Clark, E. L. Faneuf, J. T. Ferguson, W. A. Grigat, R. C. Hannenberg, W. A. Leeper, L. L. Moses, Robert A. Nyquist, Edwin F. Ottens, E. B. Saubestre, John Parina and Taylor Lyman. Company affiliations of the members were given in Part I of the article last month.

Table I – Typical Job-Equipment Relations for Alkaline Soak Cleaning

SELECTION FACTOR	SMALL PIECES*	LARGE PIECES*
Production Requirements		
Number of pieces, per hr.	300	250
Area, sq. ft. per hr.	400	1200
Weight of pieces, lb.	¼ to 5	to 1000
Equipment Requirements		
Tank dimensions		
Cleaner tank, ft.	6 × 3 × 3 deep	18 × 5 × 5 deep
Rinse tank, ft.	6 × 3 × 3 deep	18 × 5 × 5 deep
Tank volume		
Cleaner, gal.	330	2900
Rinse, gal.	330	2900
Rinse overflow, gal. per hr.	20	200
Type of overflow	Dam	Dam
Source of heat	Steam coil	Immersion burner
Heat input, Btu. per hr.	225,000	2,000,000
Operating temperature, °F.	175 to 200	175 to 200
Cost of equipment	$900	$2200

*Small pieces have dimensions of 1 ft. or less on a side; large pieces, more than 1 ft.

sistent with the soil load and quantity of material being cleaned.

This control test is made by titrating 0.1 N hydrochloric acid into a 25-ml. sample of the process solution to a phenolphthalein end point. A duplicate test is made with a fresh solution of cleaner of the desired strength; comparison of the results will indicate the amount of replenishment needed to bring the process solution to required strength.

Solution strength can also be determined by an electrical conductivity meter calibrated to indicate the amounts of alkali additions needed to bring the solution to its proper strength.

Double Titration More Accurate

Double titration depends on a chemical titration for equivalent hydroxide and equivalent carbonate. Neutralization is normally carried out with a known concentration of hydrochloric acid. The hydroxide is neutralized and the carbonate is converted to bicarbonate at an approximate pH of 8.5 (phenolphthalein). Methyl orange is added and the titration is continued until the bicarbonate is neutralized (pH = 3.8).

The calculation for the concentration of hydroxide and carbonate requires the values for the acid concentration, expressed as normality (N), and milliliters of acid used to titrate to each of the two end points. If the first end point equals A and the second B, both expressed in milliliters, then for this acid-base reaction N acid × ml. acid = N base × ml. base. The only unknown is N base. The volume of acid solution used to neutralize the hydroxide is A−(B−A); the acid used to neutralize the carbonate is 2 (B−A).

For a 1 N solution of sodium hydroxide there is 40 g. per liter of solution or 5.35 oz. per gal. For a 1 N solution of sodium carbonate there is 53 g. per liter or 7.06 oz. per gal. The concentration of the two in ounces per gallon is derived from these formulas for a 10-ml. sample of cleaner:

$$\text{Oz. per gal. } Na_2CO_3 = \frac{2(B-A) \times N \text{ acid} \times 7.06}{10}$$

$$\text{Oz. per gal. NaOH} = \frac{[A-(B-A)] \times N \text{ acid} \times 5.35}{10}$$

$$\text{Total oz. per gal.} = \text{oz. per gal. } Na_2CO_3 + \text{oz. per gal. NaOH}$$

Alkaline cleaners made up of other alkalis or containing other alkaline materials will have a double end point, but the titration does not sort out the constituents. For a test for other alkalis, make a liter of solution of the desired cleaner concentration. Titrate a 10-ml. sample as above and use the above formulas to calculate the results as though the sodium carbonate and hydroxide are actually present. The total cleaner in ounces per gallon as calculated will not be the same as the actual concentration of cleaner as-made, except in the special case of sodium carbonate and sodium hydroxide. Therefore divide the as-made concentration by the total as-calculated concentration to find a factor that will be used in further titration on the same cleaner in production.

$$f = \text{factor} = \frac{\text{as-made concentration } (x)}{\text{as-calculated concentration } (y)}$$

Therefore, for operation, f times y will equal the cleaner concentration in the production tank.

For control, the total amount of cleaner is important, as is the difference, in ounces per gallon, between the hydroxide and the carbonate. A large positive difference means more equivalent hydroxide, and normally a harsher cleaner on nonferrous alloys.

The cleaner balance may be upset because sodium hydroxide and other alkaline materials react with CO_2 in the air, particularly in spray washers. Other cleaner material will hydrolyze or transpose at a lower pH. Analysis may indicate that more sodium hydroxide should be added to counteract the change in the cleaner balance.

A typical schedule for the double-titration control test for spray and electrolytic cleaning solution is:

SPRAY

Titrate:	Each 4 hr.
Skim or overflow:	Each 3 hr.

ELECTROLYTIC

Titrate:	Each 4 hr.
Skim or overflow:	Once or twice a day

Experience should be gained in correlating the results of analysis with those of the cleaning process. The double-titration method is not a cure-all but it does provide a means of controlling solution strength and reducing consumption of the cleaner. Sampling procedure, setup time, cleaning of glassware, and actual titration and calculations average less than 15 min. per analysis, or about $3.00 per day.

Normally a complete analysis of the solution is unnecessary if it is working satisfactorily. The usual test is a titration using a phenolphthalein end point. When trouble is encountered and the cleaner is not performing satisfactorily, yet the phenolphthalein indicator shows the solution to be in proper specification range, either a more complete analysis must be made or the solution must be dumped.

The decision to dump a cleaning solution or to decant it into another tank depends on the economics of the operation. The make-up

Table II – Typical Job-Equipment Relations for Alkaline Spray Cleaning

SELECTION FACTOR	SMALL PIECES*	LARGE PIECES*
Production Requirements		
Number of pieces, per hr.	900	300
Area, sq. ft. per hr.	2,400	12,000
Weight of pieces, lb.	0.6	12
Equipment for Cleaning Stage		
Tank dimensions, ft.	20 × 5 × 4 deep	20 × 5 × 4 deep
Tank volume, gal.	3000	3000
Pump capacity, gal. per min.	1150(*a*)	850(*a*)
Pump pressure, lb.	25 to 30	25 to 30
Size of spray housing, ft.	15 × 6 × 8 deep	12 × 6 × 8 deep
Line speed, ft. per min.	15	10
Distance between centers, ft.	4	4
Hanging pattern	4 per center or 4 ft. between each 4 pieces	2 per center or 4 ft. between each 2 pieces
Riser spacing, in.	14	12
Nozzle type	V-jet(*b*)	V-jet(*b*)
Nozzle pressure, psi.	15 to 20	15 to 20
Distance, nozzle to work, in.	12 to 16	12 to 16
Cleaning time, min.	1 to 1¼	1 to 1¼
Volume delivered per nozzle, gal. per min.	4.3(*c*) to 4.9(*d*)	4.3(*c*) to 4.9(*d*)
Nozzles per riser set	15(*e*)	13(*f*)
Rinse set number	11(*c*) to 13(*d*)	11(*c*) to 13(*d*)
Solution volume pumped, gal. per min.	710(*c*) to 956(*d*)	615(*c*) to 828(*d*)
Screen area, sq. ft.	16 to 18(*g*)	12 to 14(*g*)
Mesh size	4 to 6	4 to 6
Overflow	Full-length dam	Full-length dam
Drain zone length, ft.	9	6
Motor rating	15 hp., 1750 rpm.	15 hp., 1750 rpm.
Heat source	Steam	Steam
Heat input, Btu. per hr.	4,800,000(*h*)	3,400,000(*h*)
Operating temperature, °F.	160 to 180	160 to 180
Equipment for Rinse Stage		
Tank dimensions, ft.	8.3 × 5 × 4 deep	8.3 × 5 × 4 deep
Tank volume, gal.	1250	1200
Pump capacity, gal. per min.	516 to 588	447 to 510
Pump pressure, lb.	20 to 25	20 to 25
Zone preceding rinse stage, ft.	4 (to first riser)	4 (to first riser)
Length of spray zone, ft.	7 to 10	7
Riser spacing, in.	14	12
Nozzle type	V-jet	V-jet
Nozzle pressure, psi.	12 to 15	10 to 15
Distance, nozzle to work, in.	12 to 16	12 to 16
Rinsing time, sec.	30 to 40	30 to 40
Nozzles per riser set	15(*i*)	13(*j*)
Riser set number	8	8
Screen area, sq. ft.	7 to 10(*k*)	8 to 10(*k*)
Mesh size	4 to 6	4 to 6
Overflow	Full-length dam	Full-length dam
Drain zone length, ft.(*l*)	6	6
Motor rating	7½ hp., 1750 rpm.	7½ hp., 1750 rpm.
Heat source	Steam	Steam
Heat input, Btu. per hr.	2,200,000	1,800,000
Operating temperature, °F.	140 to 160	140 to 160

*Small pieces have dimensions of 1 ft. or less on a side; large pieces, more than 1 ft. (*a*) Hydrostatic head of 50 to 60 ft. (*b*) Produces flat spray pattern with maximum impingement. (*c*) For cleaning time of 1 min. (*d*) For cleaning time of 1¼ min. (*e*) 9 to 10 in. on centers with alternate risers staggered. (*f*) 12 in. on centers with alternate risers staggered. (*g*) 1½ sq. ft. screen area for each 100 gal. per min. of solution pumped. (*h*) Assuming 8°F. temperature drop due to exhaust heat losses, heat losses to cold parts, heat dissipation through sides and spray; heat-up time of solution figured at 1 hr. (*i*) 9 to 10 in. on centers with alternate risers staggered. (*j*) 12 in. on centers with alternate risers staggered. (*k*) 1½ sq. ft. screen area for each 100 gal. of solution pumped per min. (*l*) Followed by dry-off (if liquids are not pocketed) of 2 to 3 min. at 300 to 350°F. If recesses on parts cause pocketing of liquids, air blow-off should be used.

cost must be compared with the labor costs for handling the solution. For example, if a proprietary spray cleaner is being used at 15¢ per lb. at a concentration of 1 oz. per gal. in a 3200-gal. tank, the material make-up is only $30.

With installations that clean as much as 100,000 sq.ft. every 8 hr., it is common practice to dump the cleaner each week. Sometimes there is very little soil on the incoming work and the solution may be used for longer periods.

Equipment Requirements

The factors affecting selection of a cleaning method (such as size, shape and weight of the work and the degree of cleanliness required) also influence the selection of equipment. The equipment chosen should be adequate not only for present work volumes but for those likely in the near future.

Small parts can be handled in baskets and rotating drums or barrels; parts easily damaged are treated individually by hanging them on racks. Box-like parts will require careful placing of spray jets to reach the recessed surfaces. Recesses are often best cleaned in electrolytic tanks.

Equipment requirements for typical jobs for each of the alkaline methods are reported in Tables I through V. Systems employing combinations of methods do so to overcome the limitations of a single method.

Soak cleaning equipment is the least expensive of the installations used with alkaline cleaning. It consists of a tank cleaner, one or two tanks for the rinse, an air exhaust system, a source of heat, with the necessary piping for supplying water and discharging spent cleaner and rinse. Tank construction is dealt with on p. 109. Depending on the size, weight and quantity of parts in each load, the work can be handled manually or mechanically. Table I gives typical relationships of equipment size with size and quantity of parts to be cleaned.

Spray cleaning equipment is almost always multistage and conveyerized. This accounts for the high cost of equipment. Depending on the part to be cleaned, type of soil and degree of cleanliness desired, spray washing machines may use two, three or four stages. Table II shows typical job-equipment relations for spray cleaning, and Fig. 1 (p. 110) shows a typical two-

Table III – Typical Job-Equipment Relations for Electrolytic Cleaning

Selection Factor	Barrel Work*	Small Pieces*	Large Pieces*
	Production Requirements		
Number of pieces, per hr.	50 to 150 per barrel	1250	250
Area, sq. ft. per hr.	1250	1250	1250
Weight of pieces, lb.	0.1 to 1¼	¼ to 5	10 to 50
Area of pieces	0.1 to 20 sq. in.	¼ to 2 sq. ft.	2 to 10 sq. ft.
	Equipment Requirements		
Tank dimensions, ft.			
Cleaning	8 × 3 × 3 deep	6 × 3 × 4 deep(a) 11 × 4 × 6 deep (b)	6 × 3 × 4 deep(a) 11 × 4 × 6 deep(b)
Rinse	4 × 3 × 3 deep	6 × 3 × 4 deep(a) 11 × 4 × 6 deep(b)	6 × 3 × 4 deep(a) 11 × 4 × 6 deep(b)
Tank volume, gal.	500	500(a), 1800(b)	500(a), 1800(b)
Cleaning time, min.	1 to 5	1 to 5	1 to 5
Rinsing time, min.	½ to 2	1/6 to ½	1/6 to ½
Barrel material	Plastic(c)	———	———
Rack material	———	Copper	Plastic-covered copper
Hook material	———	Plastic-covered copper	Plastic-covered copper
Current density, amp. per sq. ft.(d)	15 to 30	25 to 100	25 to 100
Voltage	12	6	6
Heating unit	Steam coil	Steam coil	Steam coil
Cleaning temperature, °F.	170 to 210	170 to 210	160 to 180
Cost of equipment,			
Cleaning(e)	$1000 to 3000(f)	$1000 to 3000	$1000 to 3000
Rinsing	$100 to 500	$100 to 500	$100 to 500

*Dimensions for barrel work are less than 6 in. on a side; for small pieces, 6 in. to 1 ft.; for large pieces, more than 1 ft.

(a) For manually operated work carrier. (b) For hoist-operated work carrier. (c) Temperature-resistant plastic; steel barrels can be used if the electrocleaned parts will not be plated. (d) Minimum average of 50 amp. if parts have recesses and blind holes. (e) Includes ventilating equipment. (f) Includes barrels.

stage steam-heated spray-type washing machine.

In general, the machine consists of steam-heated alkaline cleaner tank, hot water rinse tank, and hot air drying zone housed in a steel shell. The shell is large enough to permit a steel wire mesh conveyer or vertical racks carrying the work to be conveyed through the machine. When a conveyer belt is used, spray nozzles are mounted above and below the belt to spray the cleaning solution and rinse water on the work. Spray nozzles may be mounted vertically to spray work held on vertical racks while passing through the machine.

Solutions are pumped to the spray nozzles from their respective tanks. Tanks are baffled to keep the cleaning solution from the rinse tank and are provided with temperature controls, pumps, water overflow weirs, steam-heating coils and regulators. The machine should also have an adequate blower-exhaust system.

A large proportion of the total volume of solutions used for alkaline **electrolytic cleaning** (as well as soak and spray) is in automatic plating machines. Here the entire cycle and machine may be specifically designed to process one part or type of part at a relatively high production rate. Automatic machines usually employ several cleaning methods. Comprehensive discussion of all the aspects of alkaline electrolytic cleaning in automatic machines is not practical here. However, the proper application of alkaline electrolytic cleaning is essential for the success of nearly all processes (especially plating) which employ automatic processing machines. The data reported in Table III are for typical production jobs rather than recommendations for specific production requirements.

Because of the high operating temperatures and the liberation of hydrogen and oxygen in an explosive ratio, all electrolytic cleaning tanks should be adequately ventilated. Normally a blower-operated exhaust is suitable but, if tank width exceeds 3 ft., it may be desirable to utilize a so-called "push-pull" system.

Spray-rotary cleaning employs a washing machine equipped with a rotary drum of perforated steel for conveying the work through the machine. The drum is mounted so that it slopes toward its exit end. A stationary steel tube or header pipe provided with spray nozzles is mounted horizontally in the center of the drum through which the alkaline cleaner and rinse

Table IV – Typical Job-Equipment Relations for Spray-Rotary Cleaning

Selection Factor	Small Pieces★
Production Requirements	
Number of pieces, per hr.	400 to 1000
Area, sq. ft. per hr.	8 to 200
Weight of pieces, oz.	2
Area of pieces, sq. in.	3 to 30
Equipment Requirements	
Tank dimensions, ft.	
Cleaning	7 × 3 × 3
Rinse	5 × 3 × 3
Tank volume, gal.	
Cleaning	400
Rinse	325
Cleaning time, min.	3
Rinsing time, min.	2
Pump capacity, gal. per min.	75
Nozzle type	Flat-jet or V-jet
Nozzle pressure, psi.	15 to 25
Drum size, in.	24
Drum speed, rpm.	2 to 5
Heat source	Steam coil or immersion burner
Operating temperature, °F.	170 to 190

★Dimensions of 1 ft. or less on a side.

Table V – Typical Job-Equipment Relations for Spray-Rotary Brush Cleaning

Selection Factor	Large Pieces★
Production Requirements	
Number of pieces, per hr.	600 to 700
Area, sq. ft. per hr.	2000
Weight of pieces, lb.	4
Area of pieces, sq. ft.	3
Equipment Requirements	
Tank dimensions, ft.	
Cleaning	13 × 3½ × 2¼ deep
Rinse	13 × 3½ × 2¼ deep
Tank volume, gal.,	
Cleaning	400
Rinse	400
Cleaning time, sec.	30 to 40
Rinsing time, sec.	15
Pump capacity, gal.	75
Nozzle type	V-jet or flat-jet
Spray pressure, psi.(*a*)	15 to 25
Type of brush	Nylon, Tampico or equivalent(*b*)
Type of conveyer	Chain-driven mesh belt
Conveyer speed, ft. per min.	40 to 60
Heat source	Steam coil or immersion burner
Operating temperature, °F.	180 to 200

★Dimensions greater than 1 ft. on a side.

(*a*) Pressure at pump. (*b*) Life of brushes is 3 to 6 months.

Table VI – Approximate Relative Costs in Metal Cleaning
Typical Cost Relations for Cleaning Steel Parts in Large Quantities*

Method	Direct Labor	Disposal Labor	Mate-rial	Water	Energy	Main-tenance	Over-head†	Total of Columns to Left	Initial Cost of Equipment
Vapor degreasing	5	2	9	0.1	2	0.5	2	20.6	50
Solvent cleaning (tank)	5	2	9	0	0.6	0.4	2	19.0	10
Alkaline cleaning									
Tank, hot	6	2	4	1	1	0.6	2	16.6	15
Spray, hot	5	2	2	1.2	3	0.9	2	16.1	40
Electrolytic	6	2	4	1	2	0.5	2	17.5	70
Emulsion cleaning									
Tank, hot	5	2	3	1	2	0.6	2	15.6	15
Spray, hot	5	2	2	1.2	4	0.9	2	17.1	40

*Numbers in the first eight columns are on the same scale. Numbers in the final column (initial cost of equipment) are on a scale of 100 for comparison in that column only, and have no relation to the scale used in other columns.

†Overhead, shown as a nominal minimum is the same for all processes. It will usually vary more with local conditions than the factors shown in the six columns to left. Source: 1955 Supplement to ASM Metals Handbook, p. 170

water are pumped from a reservoir tank heated by steam coils. The parts are sprayed as they travel through the drum and the solutions are drained back into the tank. The three stages in the machine are normally hot alkaline cleaning, hot water rinse and hot air drying. Equipment for typical jobs is described in Table IV.

This type of washing machine and process is suitable for small punch press and machined parts for fast removal of cutting and drawing oils prior to assembly or subsequent processing. It has the advantage of processing large quantities of small irregularly shaped parts at low cost. Mild alkaline cleaners with good wetting and low foaming characteristics are used.

Spray-rotary brush cleaning, in a typical application, would be used for cleaning flat sheet, blanks and coil stock prior to the application of coatings for a press-forming operation. In such an application, a conventional four-stage washing machine is employed. This is equipped with a rubber belt to convey the work through the rotary brush spray cleaning and rinsing stages, a steel wire mesh belt to convey the work through a soap-coating zone and a drying oven. Typical job-equipment relations are shown in Table V.

Steam gun cleaning is employed on parts too large for existing tank and spray equipment, or parts to be cleaned in a quantity too small to justify investment in special equipment. Steam guns are relatively inexpensive and can be operated from the central steam line or from auxiliary steam-producing equipment. Also the steam-cleaning equipment can be made portable and used outdoors. When operated inside, an exhaust hood should be used. A separate tank, preferably heated, is required for the alkaline

Table VII – Typical Costs Per Square Foot for Soak Cleaning Large Parts Prior to Phosphating
Production rate: 20,000 sq. ft. per month*

Item	Cost Per Square Foot
Utilities	
Water: 4.04 gal. per sq. ft. @ \$0.00009 per gal. (a)	\$0.00036
Gas: immersion burner heating costs at \$5.50 per day	0.00577
Material	
Cleaner: 1000 lb. per month @ \$0.13 per lb.	0.00650
Direct labor	(b)
Indirect labor	
Solution make-up, 2 hr. per month @ \$2.00 per hr.	0.0002
Solution additions, ¼ hr. per day	0.00053
Maintenance	
Labor to clean tank, 6 hr. per month @ \$2.00 per hr.	0.0006
Labor to maintain equipment	
Pipefitter's time 5 hr. @ \$2.40 per hr. (\$0.0006)	
Electrician's time 2 hr. @ \$2.00 per hr. (\$0.0002)	0.0008
Labor for solution analysis, ½ hr. per day @ \$2.50 per hr.	0.0013
	\$0.01606
Total cost per month	\$321.20

*Costs based on 16-hr. day, 21 days per month.

(a) Make-up, 3000 gal. plus 500 gal. daily loss—13,500 gal. per month; rinse overflow, 200 gal. per hr.—67,200 gal. per month.

(b) Cost of racking charged to phosphating.

cleaning solution. An injector nozzle mixes the solution with the steam. Sufficient heat may be produced from the steam to dry the parts. Rinsing is unnecessary except when the residue from the alkaline cleaner would interfere with subsequent operations. The steam gun is heavy and tiring to the operator for continuous work and a rope and pulley arrangement or other counterbalancing device should be considered.

The concentration of the cleaning compounds may vary from ⅛ to 2 oz. per gal., depending on the type of soil and surface to be cleaned.

Table VIII—Typical Costs for Alkaline Spray Cleaning prior to Nickel Plating Production Rate: 79,750 Sq. Ft. Per Week*

Item				Cost Per Week	Cost Per Sq. Ft.
Utilities					
Water: Make-up and rinse, 10 gal. per min. @ 0.90 per 1000 cu. ft.				$ 5.76	$0.00007
Steam: 1300 lb. per hr. @ $1.50 per 1000 lb.				156.00	0.00195
Electricity: 17,100 watts @ $0.009 per kwh.				12.30	0.00015
Material	Lb. Per Week	Cost Per 100 Lb.	Cost Per Week		
Cleaner	625.25	$6.45	$40.33		
Metasilicate	68.25	7.05	4.81		
Sodium hydroxide	51.75	6.17	3.19	48.33	0.00061
Direct labor				(a)	(a)
Indirect labor					
Solution make-up, additions, analysis, material handling—255 min. per week @ $2.10 per hr.				8.93	0.00011
Maintenance					
Labor to clean tanks, nozzles, and screens, 16½ hr. per week @ $2.00 per hr.				33.00	0.00041
Equipment					
Pipe fitting, material and labor			$0.90		
Machinist's labor			0.50		
Electrician's labor			2.10	3.50	0.00004
Total costs				$267.82	$0.00334

*Costs based on 16-hr. day, 5 days per week.
(a) Cost of racking charged to plating.

Equipment Construction

Except for the fact that spray (Fig. 1) and electrolytic (Fig. 2) methods employ spray heads or electrodes and therefore may require a tank size different from that for soak cleaning, the tanks are essentially similar for each method of cleaning.

Carbon steel makes a suitable container for alkaline cleaning solutions. Linings are sometimes used to prevent contamination of the solution and to insulate against stray electrical currents if the tank is part of an automatic system having either an electrolytic cleaning or an electroplating cycle. Hot rolled mild steel plate is used for tank construction, the minimum thickness of the plate being ¼ in. for a small tank (3 × 6 × 3 ft. deep). Tanks 6 ft. deep or more require thicker walls, horizontal braces, and buttresses to brace the sides. All tanks should have a rim of angle iron or other structural shape welded to the upper edge of the sides for reinforcement and for supporting equipment and accessories. Tank joints should be double welded and the tank bottom should be pitched to assist draining and washing out of solids and sludge.

An overflow dam located opposite the operating side of the tank provides a means for disposal of soil skimmed from the top of the cleaning solution. A manually operated valve in the drain for the overflow dam is used to prevent loss of solution when large parts are cleaned. All valves controlling drainage and water, steam, gas and air to the tank should be located for safe accessibility.

Tank heating is by means of a steam coil or immersion burner. These should be located on the operating side of the tank so that the rolling action imparted to the solution by convection currents is toward the back of the tank. Shields with 3-in. diameter holes on 6-in. centers are often placed in front of the heating units to increase the agitation.

The steam coil and the containing tube for the immersion burner should be constructed in the form of an S, and of a size to allow 4 in. of solution above and below it. The steam coils and burners should be capable of heating a solution to operating temperature within 2 hr.

Agitation stronger than the convection currents caused by steam coils and burners can be obtained with impellers, recirculative centrifugal pumps, or by an air line with an outlet at the bottom of the tank. The air can be supplied by a low-pressure compressor or by the factory

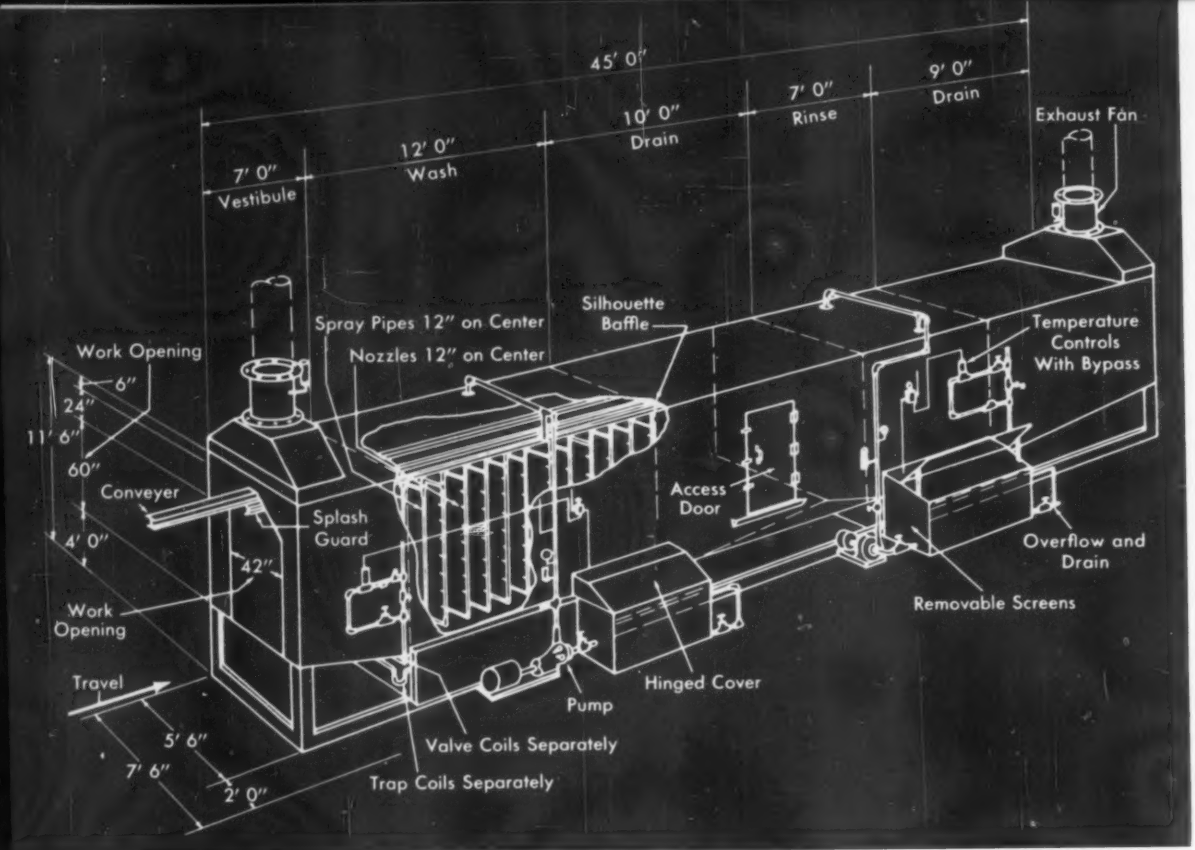


Fig. 1 – Multistage Spray Cleaning Unit. Lengths are based on a conveyer speed of 10 ft. per min. Although the initial cost of equipment is usually high, spray cleaning is justified by the high production rate which is possible

high-pressure line if it is filtered and a safety valve is installed at the cleaning tank to prevent the solution bumping out because of surges in pressure. Excessive agitation will cause alkaline cleaning solutions to foam but this can be controlled through proper selection of surface active agents, particularly the nonionics.

Ventilation, required for all cleaning tanks, is most effective with a push-pull system in which fresh air is forced over the operating side of the tank and drawn at the back of the tank. Exhaust hoods placed at the back of the tanks will give efficient service if the suction is at least 100 cu.ft. of air per min. per sq.ft. of surface area of cleaner. If a push-pull system is used, it should move air across the surface of the tank at a minimum rate of 75 cu.ft. per min. per sq.ft. of surface area.

Equipment Maintenance

Alkaline cleaning equipment made of steel usually offers no serious maintenance problems because the solutions retard rusting. The moving parts, motors, pumps, heating equipment, nozzles, screens, and conveyers are potential sources of trouble. Systematic maintenance will help prevent costly downtime during production.

Maintenance of soak equipment requires preventive measures as follows: (*a*) Steel tank exteriors should be protected with an alkali resistant paint. Inaccessible surfaces of tanks on automatic machines should be given corrosion protection at the time of installation if removal of the tank for maintenance is too expensive. Rubber-lined, plastic-lined, or stainless steel tanks may be used. Tank interiors should be thoroughly cleaned of sludge each time the solution is dumped. (*b*) Steam coils require thorough cleaning at least once a year or whenever the caking of deposits seriously hampers the transfer of heat. (*c*) Piping should be protected with an alkali-resistant paint. (*d*) Temperature control elements should be cleaned each time the solution is dumped. (*e*) Hood interiors should be steam cleaned at three-month intervals to maintain an efficient rate of exhaust. An alkali resistant paint should be applied to outside hood surfaces.

Spray equipment should receive preventive measures as follows: (*a*) Tank maintenance as

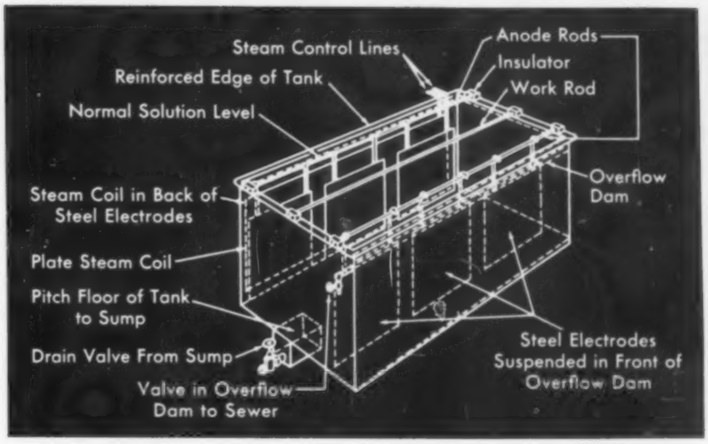


Fig. 2—Essential features of a Typical Electrocleaning Tank. Porcelain insulators are attached to the bottom edges of the electrodes to prevent contact with the tank sides

given in the schedule for the soak method. About once every three months, the tank interior should be washed with an inhibited acid to remove accumulated solids. The tank is then thoroughly rinsed with water and flushed with an alkaline solution to neutralize any remaining acid. (*b*) Spray nozzles should be inspected each day for adjustment of the spray pattern. Nozzles should be removed and cleaned at least once each week by soaking in an inhibited acid or chromic acid. (*c*) Screens require daily cleaning. Heavier soil or soil containing lint, excelsior or other material that clogs the screen will require removal more often. Badly clogged screens can be blast cleaned with fine shot. (*d*) Risers require flushing out at least once each week. They should be cleaned of scale at least once a year. (*e*) Pumps should be inspected every two months and dismantled at least once a year for minor repairs such as replacement of packings and glands. (*f*) Temperature recording equipment should be tested every two months. (*g*) Heating systems (whether closed steam coils, live steam or electrical immersion heating elements) require inspection and cleaning at least once a year.

Electrolytic equipment components needing periodic attention are: (*a*) Bus bars and contact points should be scrubbed lightly with emery cloth at the beginning of each shift, and more thoroughly once a week and when the solution is dumped. (*b*) Electrodes should be cleaned at the time the solution is dumped. (*c*) Temperature control elements should be cleaned at the time solution is dumped. (*d*) Rectifiers need to be inspected weekly and completely cleaned and repaired once a year. (*e*) Motor-generator sets need to be inspected weekly. (*f*) Electric meters should be checked for accuracy once a year. (*g*) Racks need to be cleaned and inspected each work shift. (*h*) The heating system should be cleaned and inspected at least once a year.

Cost of Equipment

Although the selection of an alkaline cleaning method, or combination of methods, is influenced by the kind of soil to be removed, the size, shape, and weight of the work, kind of material being cleaned, and the nature of subsequent operations, the most important single factor is the volume of work to be processed. Automation and semi-automatic multi-stage methods are justified when the volume is great enough to amortize the equipment cost and obtain savings through reduced labor.

A cleaning job should first be evaluated to establish the requirements from a cleaning standpoint. Then the most economical method should be selected to meet these requirements.

Approximate relative costs for tank, spray and electrolytic cleaning of steel parts in large quantities are listed in Table VI, in comparison with vapor degreasing, solvent cleaning and emulsion cleaning. The three cost examples dealt with in Tables VII, VIII and IX may serve as a rough guide in predicting costs for similar applications.

Cost Examples

In Table VII, costs are reported for soak cleaning large parts prior to phosphating. Because the number of square feet of work put through the machine was limited by the longer cycle of the phosphating operation, the time inside the machine was great enough so that cleaning could be done at no extra labor cost for handling.

Table VIII gives the costs for spray cleaning prior to nickel plating. The system has two lanes

Table IX – Typical Costs of Electrolytic Cleaning

Item	Tank 1*	Tank 1-A*	Tank 2*	Tank 3*	Cost Per 10,000 Sq. Ft. Cleaning			
					Tank 1	Tank 1-A	Tank 2	Tank 3
Water for rinsing and make-up								
Gal. per min.	10	10	15	5				
Hours	16	16	16	24				
Cost per week	5.76	5.76	8.64	4.07				
Cost per 1000 cu. ft.	0.90	0.90	0.90	0.85	2.40	1.54	1.08	4.07
Steam: lb. per hr.	100	110	135	35				
Hours	24	24	24	24				
Cost per 1000 lb.	1.50	1.50	1.50	1.15				
Cost per week	18.00	19 80	24.30	4.83	7.50	5.29	3.05	4.83
Electricity: amp. per sq. ft.	23	23	30	50				
Hours	0.035	0.035	0.058	0.033				
Voltage	6.4	10.0	8.0	6.0				
General efficiency	0.75	0.75	0.75	0.75				
Cost per kw-hr.	0.009	0.009	0.009	0.01	0.62	0.97	1.67	1.33
Materials, additions and make-up								
Cleaner, lb.	220	100	720	70				
Cost per 100 lb.	6.50	7.25	7.25	10.00	5.96	1.94	6.54	7.00
NaOH, lb.	52		80					
Cost per 100 lb.	4.00		6.14		0.86		0.62	
Wetting agent, lb.	0.9	1						
Cost per 100 lb.	30.00	30.00			0.11	0.08		
Indirect labor								
Initial make-up, min. per week	30	30	60	30				
Cost per week	0.90	1.00	2.00	1.00	0.38	0.27	0.25	1.00
Additions, min. per week	50	15	100	15				
Cost per week	1.50	0.50	3.30	0.50	0.62	0.13	0.41	0.50
Analysis, min. per week	75	75	75	15				
Cost per week	2.25	2.50	2.50	0.75	0.94	0.67	0.31	0.75
Material handling, min. per week	12	12	20					
Cost per week	0.35	0.40	0.70		0.15	0.11	0.09	
Maintenance of equipment								
Pipe fitting, material and labor	0.80	0.90	0.90	0.40	0.33	0.24	0.11	0.40
Electrician, labor	0.90	1.00	1.00	0.40	0.38	0.27	0.13	0.40
Machinist, labor	1.90	2.10	2.10	0.20	0.79	0.56	0.26	0.20
Total cost† per 10,000 sq. ft. cleaning					21.04	12.07	14.52	20.48

*Capacity of tanks per week: Tank 1: 24,000 sq. ft.; Tank 1-A: 37,400; Tank 2: 79,750; Tank 3: 10,000 sq. ft.
†Does not include cost of racking or of unloading

and is loaded manually. The racks continue on the same conveyer through subsequent operations of cleaning and plating to the unracking position. This cleaning machine was installed to reduce cleaning costs. The cleaning operation presented an installation problem because it was necessary to fit the machine in a small space. The number of nozzles per unit length is greater than normal, and thus more than the normal amount of cleaner is sprayed in comparison to the holding capacity of the tank.

Production rates in this machine vary over the following ranges:

Approximate Size	Maximum Parts Per Rack	Maximum Parts Per Hr.
8 × 8 × 8 in.	6	900
½ × 3 in. diam.	56	8400

Average rate: 2000 parts per hr. or 1000 sq.ft. per hr.

Labor costs, which were charged to the plating operation, would be the largest single item if the washer were not an integral part of the plating line. An average of 40 man-hours would be needed to rack, unrack and handle parts on each shift for this volume of work. For two shifts per day, at $2.10 per hr. and 79,750 sq.ft. per week, labor costs would be $840 per week, or $105 per 10,000 sq.ft. – that is, about three times as much as the total of all other costs shown. The importance of incorporating the washer into a conveyerized line becomes obvious. The method would allow the operator to act as racker and directly place the part into the cleaning cycle.

Depreciation costs on equipment can be estimated on a straight-line basis for 15 years. Original cost of equipment, including installa-

tion, is \$9000; cost per 10,000 sq.ft. is \$1.45. Most accounting departments lump this and other costs into an overhead figure or percentage of direct operating costs. As some items are already included in the table, a figure approximately 20% greater than the totals would cover all other costs.

Production at other rates can be estimated from these cost figures. However, cutting production in half would not cut all costs proportionately. At this production rate, steam required would be about two thirds that at full production, assuming the same tank volume; solution maintenance would be lessened by 25 min. each day, equipment maintenance by the same amount; labor to clean equipment would be brought down to about two thirds.

Electroplating requires a prior electrolytic cleaning method. In the examples shown in Table IX costs shown are only those of the electrolytic cleaning and subsequent water rinse, even though the electrolytic method normally follows soak or spray cleaning. The table compares the cost distribution for three electrolytic tanks. All information on Tanks 1 and 2 has been averaged and computed on the basis of a 16-hr. day, five-day week. Tank 3, at a different plant, has been averaged and computed on the basis of a 24-hr. day, five-day week.

Tank 1 follows a soak cleaning system and is used to clean buffed copper parts. The two different production volumes for Tank 1 and Tank 1-A indicate the variation in the cost of operating this tank with a change in cleaner and a change in production. The parts measure 5 × 6 × 9 in.

Tank 2 handles both steel and buffed copper plated parts. It is preceded by a spray system for removing the more readily observed soil, such as oil and heavy buffing compounds. Parts processed in this tank are not larger than 2 × 2 × 1 ft. Tank 3, which employs a hoist for handling the racks, is used to clean steel parts that have been processed through a vapor degreaser to remove corrosion-preventive compounds. Parts vary in size from 2 × 2 × 4 in. to 2 × 2 × 3 in.

Table IX shows electrolytic cleaning to be less costly than the soak or spray cleaning operations dealt with in Tables VII and VIII. This can be misleading unless it is realized that the example of Table IX applies only to the electrolytic cleaning and water rinse. These supplement other cleaning operations in the same production line. The bulk of the soil was removed in the earlier processing, which accounts for the low maintenance, fuel consumption and material costs shown for the subsequent electrolytic cleaning operation.

Hazards With Electrolytic Cleaning

Certain hazards are inherent in electrolytic cleaning because of the evolution of large volumes of gases. The noisy implosions or "banging" commonly experienced in electrolytic cleaning are nearly always the result of violent combination of oxygen and hydrogen in the presence of a spark. Also, the oil trapped in the foam can produce flames and smoke. This can be controlled or eliminated by keeping the foam blanket on the cleaning tank shallow enough to prevent excessive entrapment of these gases without defeating the normal function of the foam blanket in protecting personnel from the toxic effects of caustic mist. An auxiliary blower may be used advantageously to blow some of the foam away from the area where parts are immersed and removed. Sparks may be caused by an arc between opposite electrodes or between the electrodes and the electrolyte but they are usually associated with the immersion or removal of the rack from the solution.

Tests for Cleanliness

The final evaluation of the effectiveness of an alkaline cleaner should come from a performance test. There are eight well-known methods of determining the approximate cleanliness of the work surface:

1. The water-break test is a simple one which is widely used in industry. It consists of dipping the work into clean water to reveal a break in the water film in the soiled area. Since the test depends on the thickness of the applied water film, which cannot be controlled, false results can be obtained because of bridging of residues. A mild acid dip prior to testing for water break has been found advantageous.

2. The Nielson method requires that ten soiled panels be processed individually to determine the time required for each to be cleaned. Panels are checked by the water-break test and then by the acid copper test. An average of the times required to clean the ten panels is taken as a measure of the effectiveness of the cleaning solution.

3. In the atomizer test, panels are cleaned, acid dipped, dried, placed in a vertical position, and sprayed with an atomizer containing a blue dye solution. Just before the droplets begin to run down, the spray is stopped and the panel is

(Article continued on p. 172)

Staff Report

Magnesium

. . . Recognition Leads to Expanding Markets

To meet the growing demands for high performance, engineers are coming up with premium quality castings, better surface protection, and improved techniques for forging and welding. Keynote of the recent Magnesium Association convention was confidence in the potential of magnesium to move into expanding markets as a strongly competitive metal. (A-general; Mg)

A BRIGHT FUTURE is forecast for magnesium. But the industry still has a big selling job to do in making the capabilities of magnesium known and undoing some misconceptions. Only then will design engineers accept the metal in proper perspective as an important contender even in those applications where it could do a better job than other metals. These points were brought out in mid-October at the 15th annual convention of the Magnesium Association held in New York. According to J. S. Kirkpatrick, vice-president, research and development, Brooks and Perkins, Inc., Detroit, "The market research period for magnesium is over, and the market development era is now starting."

Premium Castings

Many advances in magnesium technology have come along as a result of demands of the missile and aircraft industry. Walter Gronvold, Boeing Airplane Co., Seattle, Wash., pointed out that the growth of casting usage in missiles and aircraft hinges on the availability of premium quality castings – those which have much higher mechanical properties than existing government specifications require. Primarily, better quality means that engineers can design to higher allowable strength levels with confidence. How high is a question in which Boeing is interested.

The data in Table I typify the potential improvement which is possible. Compared are properties of AZ 91 C-T 6 which must be guaranteed according to government specifications and those which Boeing thinks are realistic in

Table I – Guaranteed Mechanical Properties of AZ 91 C-T 6 Castings

	QQ-M-56 a*	PREMIUM QUALITY†
Tensile strength	25,500 psi.	34,000 psi.
Yield strength (0.2% offset)	14,500	16,000
Elongation	0.75%	5%

*Average of 3 or more specimens from the casting.
†Guaranteed minimums in critical areas.

castings of premium quality. Obviously, better quality places magnesium in a more competitive position.

How does a foundry produce premium quality castings? Mr. Gronvold points out that generally special attention must be paid to close control of foundry variables, feeding and risering, directional solidification through more effective location of chills, more rigid inspection, testing and development, and a general desire on the part of foundry personnel to produce high-quality work. But the job is not one-sided. Designers must work with foundrymen if the full potential of castings is to be realized. Merely providing a drawing of the part, new specifications calling for higher guaranteed properties, and a demand for quick delivery encourages nothing more than late delivery, requests for deviations and generally lower quality than is potentially available. Both designer and foundry suffer. Mr. Gronvold recommends that "responsible foundry engineers should thoroughly go over the preliminary sketches with the designers, and all their suggestions should be seriously considered and incorporated in the final design so as to fully exploit the advantages of castings".

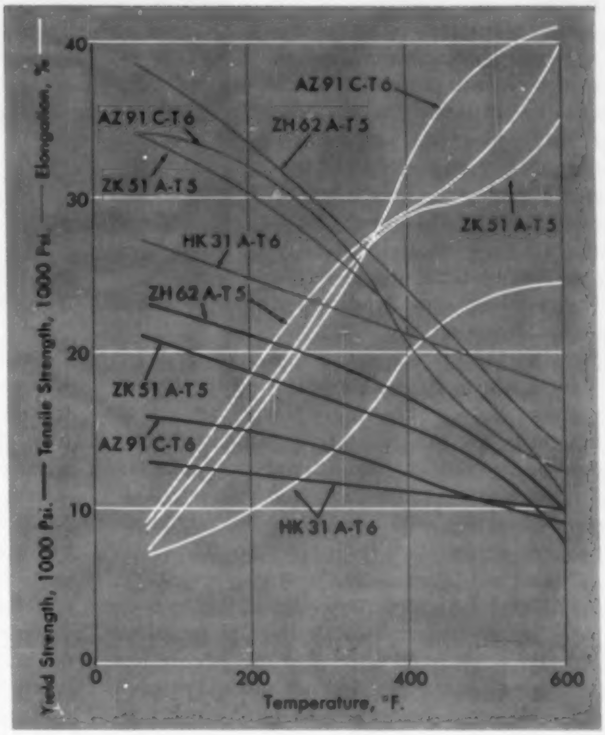


Fig. 1 – Comparison of Design Allowable Properties of Four Magnesium Alloys. (Source: Boeing Airplane Co.)

Boeing has investigated the properties of premium quality castings at rapid load rates for short times at elevated temperature. Specimens machined from larger blanks which were supplied by selected foundries were heated within 15 sec. and held at temperature for 30 sec. before

Fig. 2 – Air Conditioning Duct for a Jet Airliner. Left, welded 6061 aluminum part; right improved design in the form of a chemically milled EZ 33 casting. Change to magnesium casting cut weight by ¼ lb. and cost by $800 per part. (Courtesy South Gate Aluminum and Magnesium Co., Southgate, Calif.)

testing. The strengths of the alloys, as determined by the tensile tests at temperature, are of course not the properties which can be expected in castings. Rather, values somewhat lower than these are specified and represent properties which can be guaranteed by foundries as minimums. Some of the results of the Boeing tests are given in Fig. 1 which shows the design allowable strengths of ZH 62 A-T 5, HK 31 A-T 6, AZ 91 C-T 6 and ZK 51 A-T 5.

In line with its thinking on premium quality castings, Boeing is currently conducting evaluation tests on I-beam castings submitted in a cooperative program by a number of vendors. For each alloy, foundries were requested to supply castings with certain minimum guaranteed properties.

Since the I-beam casting is of standard shape, it will offer the opportunity after testing to compare the performance of individual foundries and alloys. It is expected that the I-beam test casting will later be used as one method of evaluating the work quality of a foundry which Boeing may want to consider as a casting source.

Static Tests

T. C. McGill, technical director, South Gate Aluminum and Magnesium Co., South Gate, Calif., told of his company's work in the static testing of magnesium castings under conditions which simulate loading in service. He pointed out that castings do not always possess cost advantages over other methods of fabrication. The competitive position of magnesium castings can be improved and cost reduction can be passed to customers. A step in this direction will come with realistic appraisal of the results of destructive tests. For one thing, they show that the usual extensive inspection of cast parts – representing 15 to 20% of the total cost of a casting – is not always necessary. For example, static tests showed that an umbilical disconnect casting for the Polaris missile made of ZK 51, although inferior in X-ray and Zyglo quality, was much stronger than the same casting made of AZ 91. The ZK 51 part was loaded to 153% of proof stress with no evidence of yielding. Tests were discontinued because the test fixture failed. On the other hand, two AZ 91 parts which were of acceptable X-ray and Zyglo quality according to standards set up by the customer failed at less than 100% of proof load. These results pinpoint one area of potential cost savings and more effective application of castings which is often limited by arbitrary standards of quality rather than performance.

Fig. 3 – Air Intake for Northrop "Talon" Lightweight Fighter. Intake is an AZ 91 casting weighing 8¾ lb. Two are required on each aircraft

According to A. J. Iler of Norair, Hawthorne, Calif., "The ability of cast materials to redistribute applied stresses in sections containing metallurgical discontinuities minimizes the deleterious effects of such discontinuities." Static testing of cast magnesium airframe parts by Norair bears this out. Working under an Air Force contract, Norair tested magnesium AZ 63 parts by simulating actual conditions such as imposed by in-flights loads. When tested to destruction, one part took 243% of the ultimate design load. At this time, the test apparatus failed but the part remained intact. It is significant that although 75% of the casting contained indications of shrinkage – a common experience in large-area, thin-walled castings – its performance was entirely satisfactory.

Experience With HK 31 Alloy

C. P. King, Marquardt Corp., Van Nuys, Calif., described his company's experience with HK 31

Fig. 4 – Transition Ring Between the Payload and Rocket Motors on the Polaris Missile. Cast of ZK 61-T 5 magnesium, part weighs only 35 lb., a 25% weight reduction from the 4130 steel assembly it replaced

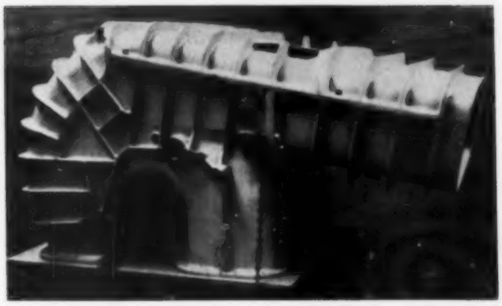


Fig. 5 — Oil Cooler Air Intake for a Reciprocating Aircraft Engine. Made up of four AZ 91 castings, it replaces a sheet metal assembly which suffered fatigue failures

alloy. Since 1952, this magnesium casting alloy has been used extensively by Marquardt, particularly in ramjet engines. It contains 3% thorium for strength and 0.5 to 1.0% zirconium for grain refinement, better fluidity and less microporosity. The alloy is strengthened by precipitation hardening after solution heat treating. Marquardt solution heat treats for 2 hr. at 1050° F., air cools, ages for 16 hr. at 400° F.

Airframe designers are often interested in thin-walled parts. For this reason chemical milling is gaining in importance. This technique, which can now be successfully applied to magnesium castings (Fig. 2), provides more latitude in design. Mr. King reported that tolerances of ± 0.002 in. are possible and that, with as little as 0.005 in. of metal removal, the surface finish can be improved significantly – for example, from 250 to 70 rms.

One difficulty with HK 31 is the segregation of thorium and zirconium. It seems to be a problem which can best be handled in the foundry with careful pouring and rigging techniques.

Improved Finishing

P. F. George, Dow Metal Products Co., Midland, Mich., discussed some of the recent developments in finishes for magnesium alloys. He reports that electroless nickel is growing in importance as a protective finish. It covers uniformly, is hard and abrasion resistant, and will improve the fatigue strength of magnesium alloys possibly as much as 20%.

Protection of magnesium in galvanic couples is a tough problem to solve. Considered noncompatible with magnesium are steel, stainless steel, Monel, copper-bearing aluminum alloys, titanium, nickel, copper and brass. Tin has been getting more attention lately as a protective coating for magnesium. It seems superior to cadmium and zinc in preventing galvanic corrosion, particularly in the rigorous salt-spray test.

Anodizing and Sealing

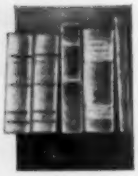
W. F. Higgins, Magnesium Elektron, Ltd., Manchester, England, described fluoride anodizing and surface sealing of magnesium alloys. The primary function of fluoride anodizing is to remove from the magnesium surface those cathodic impurities which trigger corrosion. These are picked up in the shop during normal handling. As long as the magnesium remains clean, corrosion is no problem, but so often this is neither possible nor practical. A magnesium surface which has been anodized also makes an excellent base for paints and varnishes.

Generally, surface sealing is intended to completely fill surface imperfections with a waterproof resin. By so doing, it protects the metal from chemical attack. The process requires that all moisture be removed by heating prior to the application of the resin. Thickness of one coating is about 0.0003 in. Protection is increased by multiple coatings although the thickness does not increase at the rate of 0.0003 in. per coating. It reduces corrosion at the joints between dissimilar metals and at joints where water seepage is a problem.

W. A. Hamilton, Lockheed Aircraft Corp., Marietta, Ga., described his work with forgings of HM 21 alloy which is of interest to Lockheed primarily because of its high-temperature properties. Forgeability tests reveal that the alloy is sensitive to grain orientation. If deformed at right angles to elongated grains resulting from extrusion, cracking is a problem. High pressures are required when forming thin webs. The alloy also tends to flow laterally when forged. Distribution of the metal during blocking should be regulated by die design so that vertical flow will occur in the finish operation.

Two characteristics common to magnesium welding were brought out by C. R. Sibley, Air Reduction Sales Co., Union, N. J. In consumable-electrode arc welding, the melting rate of the wire is high. Wire also takes on an oxide coating during storage. Melting rate may be slowed down by small additions of rubidium or cesium. More work is needed here.

Progress has been made in solving the oxide coating problem by redesigning the contact tube of the arc welding equipment. The new tube insures better contact with the wire and thus decreases electrical resistance.



Book Review

A Contribution to Vanadium Technology

*Reviewed by ARTHUR R. LYTLE**

THE METALLURGY OF VANADIUM, by William Rostoker, John Wiley & Sons, Inc., New York, 1958. 185 p. $8.50

IF THE TITLE implies that this book presents a full story of vanadium, the author quickly corrects this in his preface: "This book is a progress report . . . The state of knowledge of alloying and physical and mechanical properties of vanadium is far from complete . . . It cannot be said that the presently known properties of the metal and its alloys have generated much attention. In fact, . . . vanadium has not been used for any industrial purpose."

The preface sets the stage for the principal value of the book, namely, as a guide to the problems, merits and shortcomings of vanadium as a metal and alloy base. The author has assembled many bits and pieces of data which, collectively, present a good and reasonably up-to-date account of the status of vanadium.

The first chapter, about extractive metallurgy, describes clearly a number of processes for recovering vanadium. It does not differentiate between those processes which are commercially satisfactory, those which are in a research phase, or those studied speculatively. Some borderline processes have been given extensive treatment, perhaps more than they deserve. However, the researcher may appreciate the author's treatment, since production methods have not yet been standardized.

The second chapter relating to physical properties of vanadium seems reasonably complete and is crammed with the sort of data needed to appraise the metal for new applications.

*Vice-President, Research, Union Carbide Metals Co., a division of Union Carbide Corp., New York.

It is when we approach the next topic, the constitution of vanadium alloy systems, that we realize how thin is our knowledge of vanadium as an alloy base. Thirty-nine binary and eight ternary systems are reported but the data concerning most of them are very sketchy. Fourteen equilibrium diagrams, however, show each system in satisfactory detail within the areas of current interest. Again, the wide gaps in the great majority of these systems should open the door to profitable study.

The book contains an appreciable amount of data relating to mechanical properties since the effects of interstitial elements and work hardening are so important. But in the area of property determination only a beginning has been made. Here, as the author states, "It will be apparent . . . that the state of alloy development is still in its early stages . . . The mechanical properties of vanadium alloys can be varied over unusually wide limits, yet not to such optimum levels as to make it outstanding above all other metals." It is interesting that there are only six technical references in this section. Most of the curves are trend curves and need substantial confirmation. The work, however, shows the promise of vanadium-base alloys containing up to 50% titanium. Some of these alloys possess an ideal combination of low room-temperature strength and high ductility, high elevated-temperature strength and nonheat-treatability. Cost is a critical factor. In general, there is a dearth of information about creep behavior of vanadium and its alloys.

As an indication of the difficulties that arise in presenting data in book form at a relatively early stage in the development of metals, several inconsistencies appear in the last two chapters.

(Book Review continued on p. 172)

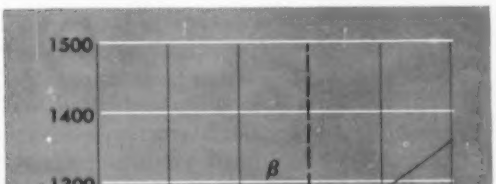
An Age Hardening Titanium Alloy

By V. C. PETERSEN, H. B. BOMBERGER
and M. B. VORDAHL*

Titanium with the proper additions of aluminum, vanadium and chromium remains 100% beta as it solidifies and cools to room temperature. Easily formable in this condition, it can be readily age hardened by heating at 850 to 950° F. This new alloy offers much promise in aircraft applications. (N7c, Q-general; Ti-b)

THE NEW BETA TITANIUM ALLOY, B-120 VCA, has the highest strength and best formability of any titanium base alloy developed to date. In fact, we believe it is as far advanced from commercial grade titanium as the 18-8 austenitic stainless steel is from plain carbon steel. With a nominal composition of 13% V, 11% Cr and 3% Al, balance titanium, the structure is 100% beta. Like austenitic steel, the high-temperature crystalline form is preserved to room temperature. This is particularly advantageous in titanium because the beta phase has excellent formability and can be aged to high strengths at conveniently low temperatures. With this combination of properties, there is naturally a great deal of interest in it. This article is intended to answer some of the many queries concerning its development.

Fig. 1 – Vertical Section of B-120 VCA Phase Diagram With Variable Aluminum. The dashed line at 3% indicates the phase relation for the alloy composition



In devising a beta alloy, the main problem is to stabilize the beta phase effectively. For this, much alloy is needed, yet if the additions are too large, the resulting composition is difficult to work, undesirably dense, or too expensive. Other important limiting factors concern melting, segregation and oxidation rates. All of these different factors had to be taken into consideration in working out the composition of this titanium alloy.

*Mr. Petersen is research metallurgist, Mr. Bomberger is supervisor, fundamental research section, and Mr. Vordahl is chief research metallurgist, Midland Research Laboratory, Crucible Steel Co. of America, Midland, Pa.

To begin with, the phase relationships and transformation characteristics were determined*. Since the important elements in this alloy are vanadium, chromium and aluminum, the diagrams of these three are shown in Fig. 1, 2 and 3. These charts can be analyzed best by discussing the functions of each alloying element by itself.

Aluminum, normally an alpha stabilizer, serves a multiple purpose in this alloy. First, it makes the use of vanadium economically feasible because alumino-thermic vanadium† can be used. Aluminum also makes transformations at less

*As to laboratory method, samples were heat treated in evacuated Vycor capsules with schedules based on a log-time plot. Times, which varied from 10 hr. at 1500° F. to 1000 hr. at 900° F., were chosen to cover all conceivably useful heat treatments. They did not necessarily yield true equilibrium. Another factor: Since the alloys used to determine these diagrams were prepared from iodide titanium, the transformation temperatures on material prepared from commercial titanium sponge may be expected to run about 50° F. higher.

†Alumino-thermic (or thermite) vanadium is vanadium reduced from its oxide with aluminum metal. Nominal composition: 85%V, 15% Al.

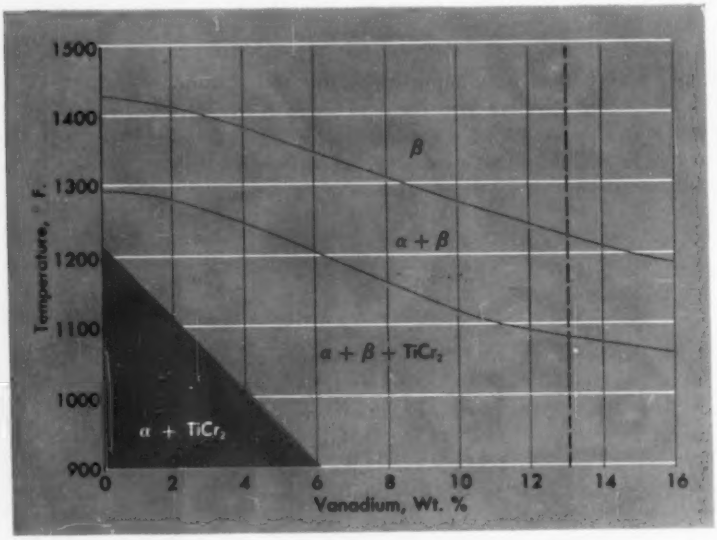


Fig. 2 – Vertical Section of Alloy Phase Diagram With Variable Vanadium. Again, dashed line indicates phase relation for alloy composition

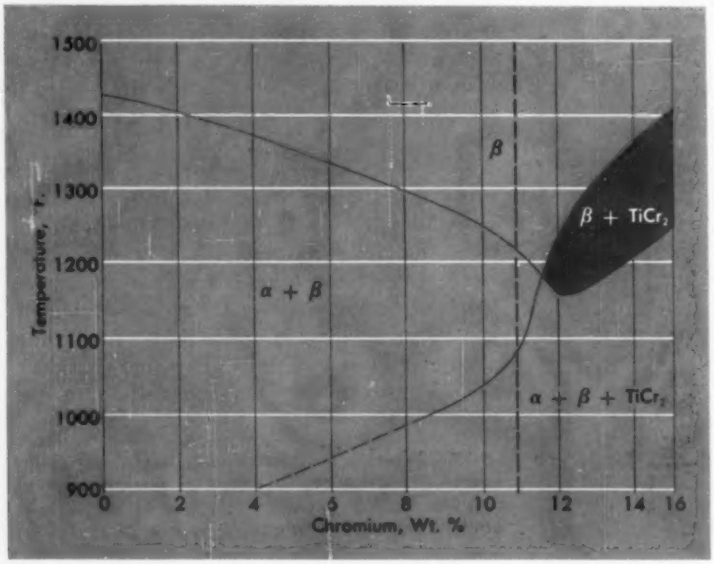


Fig. 3 – Vertical Section of Alloy Phase Diagram With Variable Chromium. Dashed line at 11% indicates phase relation for alloy composition

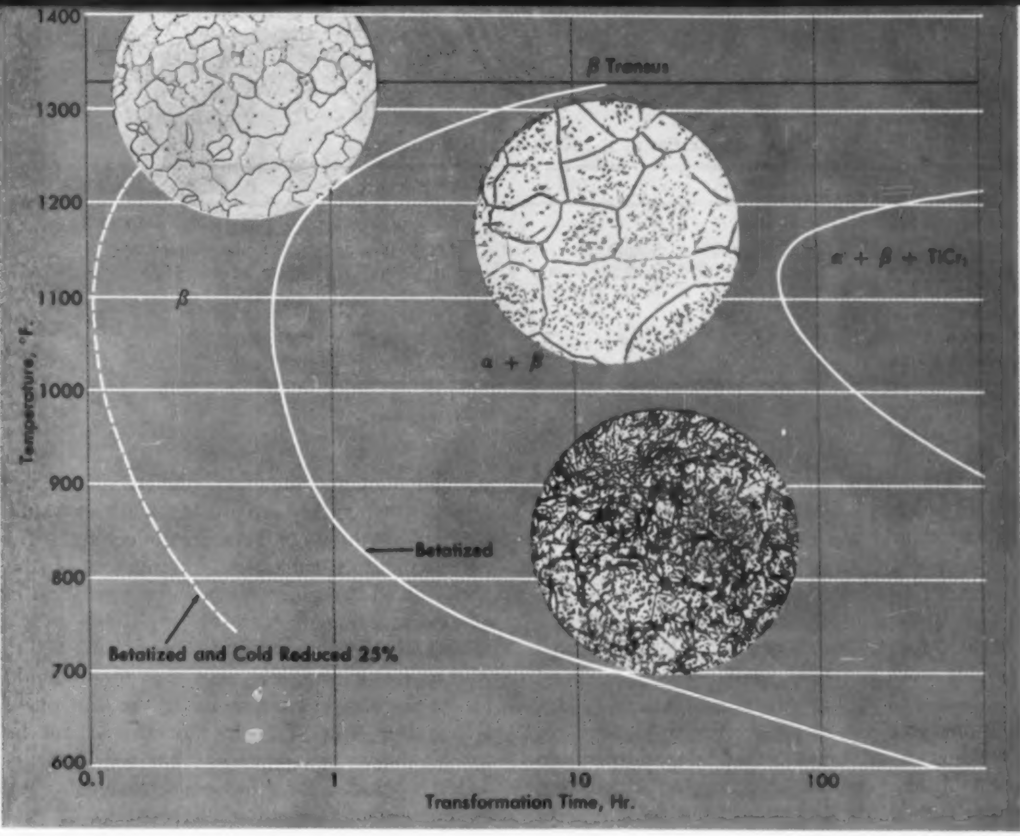


Fig. 4 – TTT-Chart for B-120 VCA. Note that prior cold rolling sensitizes the alloy so that transition time is increased five or sixfold. In the unworked condition, transition at the nose is slow enough so that air cooling is permissible. Microstructures are at 300 ×. Etchant: 1% HNO_3 and 2% HF in water

than 600° F. more sluggish. Actually, this effect is inferred. At low temperature, aging embrittlement decreases when small amounts of aluminum are added. (The lowered embrittlement may, of course, be due in part to decreased omega formation.)

Aluminum also furnishes additional solid solution strengthening, improves oxidation resistance, and promotes formation of the alpha phase during aging above about 600° F. Through the latter function, strength of the aged product is raised with less increase in transition temperature then would be caused by most alpha stabilizers.

In the solution-treated condition, however, cold formability decreased with increasing aluminum. Furthermore, the development of good aged properties becomes increasingly dependent upon suitable processing. As a compromise, the 3% level for aluminum appears to give the best combination of properties; thus, it is the amount used in our new alloy.

As an alloying element in titanium, vanadium is classified as "beta-isomorphous", a term which signifies that it stabilizes the beta phase without forming a eutectoid compound. Thus, as Fig. 2 shows, increasing the vanadium content stabilizes the beta phase, lowers the beta transus, and reduces the $TiCr_2$ rejection temperature. The latter feature is believed to help improve stability. However, when vanadium is increased beyond a certain point in titanium alloys, oxidation resistance decreases. Therefore, an additional element is needed to stabilize the beta phase further.

Of three nonvolatile and otherwise logical additions, chromium, molybdenum and iron, chromium was chosen as most suitable. In our alloy, chromium strengthens and stabilizes the beta phase, and contributes somewhat to oxidation resistance. It also forms the eutectoid compound $TiCr_2$ on aging. Figure 3 shows that, for the alloy with 13% V, 11% Cr and 3% Al, the beta decomposition proceeds as follows:

$$\beta \rightarrow \beta + \alpha \rightarrow \beta + \alpha + TiCr_2$$

Formation of the $TiCr_2$ is quite sluggish; this extends the hardening reaction during aging.

At 11% chromium, the composition approaches the critical region where the beta decomposition reaction changes from:

$$\beta \rightarrow \beta + \alpha \rightarrow \beta + \alpha + TiCr_2$$

to: $$\beta \rightarrow \beta + TiCr_2 \rightarrow \beta + \alpha + TiCr_2$$

Table I – Properties of B-120 VCA Mill Products

	Strip	Sheet	Plate	Bar
Thickness, in.	0.010	0.038	0.385	0.600*
Condition	Cold rolled	Solution treated	Solution treated	Solution treated
Aging cycle	24 hr. at 800° F.	72 hr. at 900° F.	48 hr. at 900° F.	72 hr. at 900° F.
Tensile strength, psi.	256,800	216,000	214,600	186,700
Yield strength, psi.	244,000	197,000	200,000	165,600
Elongation	3.2%	6.0%	3.5%	12.0%
Reduction in area	—	14.0%	6.3%	19.8%

*Diameter.

With this latter reaction, there is a decrease in the workability. Thus, for ductility, chromium content should not exceed 13%.

Air Cool to Beta

The isothermal transformation diagram determined for its alloy is presented in Fig. 4. All samples were betatized (mill annealed, that is) and air cooled before transformation. This diagram serves as a guide for the choice of annealing or solution-treating temperatures and in establishing suitable aging cycles. According to the curve, this alloy transforms most rapidly at 1100° F. Since transformation begins in 30 min. at that temperature, it is apparent that the alloy need only be air cooled from the solution temperature, rather than quenched, to retain the beta phase. Therefore, liquid quenching facilities are not needed. This sluggish beta reaction is also useful in welding because both weld and base metal retain the ductile beta form.

The TTT characteristics of this alloy are changed considerably by cold working, as is seen in Fig. 4. A 25% cold reduction results in a five to sixfold increase in the rate of alpha formation.

The $TiCr_2$ rejection curve in Fig. 4 was determined by X-ray diffraction, since alpha and $TiCr_2$ are quite fine at low temperatures (900° F.) and therefore appear alike to the eye. Generally, X-ray diffraction is not as sensitive for phase detection as optical metallography. The latter method was used in determining the beta to alpha + beta line. Since the $TiCr_2$ curve represents about a 5% $TiCr_2$ rejection, the strengthening effect occurs sooner than indicated.

Omega Not a Problem

On some alloys of this type, beta decomposition to alpha is not direct, but is accompanied by the formation of a transitional phase termed omega. This phase has been found in alloys of titanium with manganese, chromium, iron, molybdenum, and vanadium (the beta-stabilizing elements) when they are present in amounts sufficient to retain some beta on quenching. The chromium and vanadium formulation of this alloy would therefore suggest the formation of omega on aging.

Actually the alloy ages so slowly in the 800 to 950° F. range generally used that there should be no large concentration of the omega phase at any one time. Therefore, it should not be troublesome. In fact, omega has not been detected when the alloy has been treated by any of the normal processing methods.

Mechanical Properties Are Excellent

Primarily designed for sheet, this alloy naturally attains its best properties in that form. Thin sections are believed to behave better than heavier sections because they have a greater amount of cold work. This means greater structural refinement, and increased degree of micro uniformity on subsequent aging. Typical tensile properties of this alloy in various section sizes are shown in Table I.

To sum up, B-120 VCA is a titanium-base alloy with a relatively large amount of beta stabilizers to maintain the full beta structure through air cooling and forming. The retained beta has superior formability, and yet is not so stable it cannot be aged conveniently to high strengths. Under the best aging conditions studied to date (based on the equilibrium and kinetics data given in this paper, and subject to improvement as current investigations are extended), B-120 VCA foil has attained strengths in excess of 250,000 psi. Because this alloy is considerably lighter than steel, its strength-weight ratio (1.5 million) is one of the highest available in any structural metallic sheet. This property alone should make the alloy extremely useful in aircraft applications where weight conservation is a must. The future holds much promise for the all-beta titanium alloys.

Staff Report

Spotlight on Welding

Testing techniques designed to probe the mysteries of spontaneous brittle fracture were revealed at the Fall Meeting of the American Welding Society. Also described were recently developed welding methods and inspection procedures. (K-general, Q26s)

SOME IMPORTANT CONTRIBUTIONS to our understanding of the problem of brittle fracture in welded structures were made at the American Welding Society's Fall Meeting in Detroit.

In the session on "Toughness in Steel Weldments", A. Vinckier of Westinghouse Research Laboratories discussed an experimental method for studying the problem. He pointed out that brittle fracture in welded structures occurs spontaneously — a ship breaks in two while resting at a pier, bridges collapse while not carrying any traffic. Why these failures should occur under no-load conditions is even more perplexing when one considers that brittle cracks ensue in laboratory tests only when stresses exceed the yield stress of the metal involved. It has been suspected for some time that residual stresses induced by welding or torch cutting are prime factors in the catastrophic failures and that they raise the transition temperature and set the scene for unexpected, spectacular failure.

Brittle Fracture in Test Plates

Dr. Vinckier's work was directed at reproducing spontaneous brittle fracture in laboratory specimens — a significant step in finding clues to why such failures occur. For his tests he used 4-ft. diameter disks, ¾-in. thick, of A.S.T.M. A 7 semikilled commercial plate. A 16-in. diameter section was cut from the center of each disk. Into this opening was welded a 16-in. diameter disk containing a 4½-in. square hole. This method of fabrication results in the buildup of residual stresses in the inner disk — tensile near the hole, balanced by compressive stresses toward the outside diameter. Cracks were induced in the plate by cooling a corner of the square hole with liquid nitrogen. Temperature and strain measurements along the expected path of the crack were taken.

All plates developed spontaneously formed cracks during localized cooling with the exception of one which was stress-relieved at 1150° F. after welding. This plate did not crack even when two opposite corners of the hole were notched with a chisel just after localized cooling. Residual stresses introduced again by heating one corner followed by severe cooling in that corner resulted in spontaneous cracking.

Dr. Vinckier concludes that brittle failure occurs when the temperature drops below the transition point of the metal, when high residual tensile stresses are present around a notch or defect where plastic deformation has occurred, and when stress, such as would be caused by localized cooling, is externally applied.

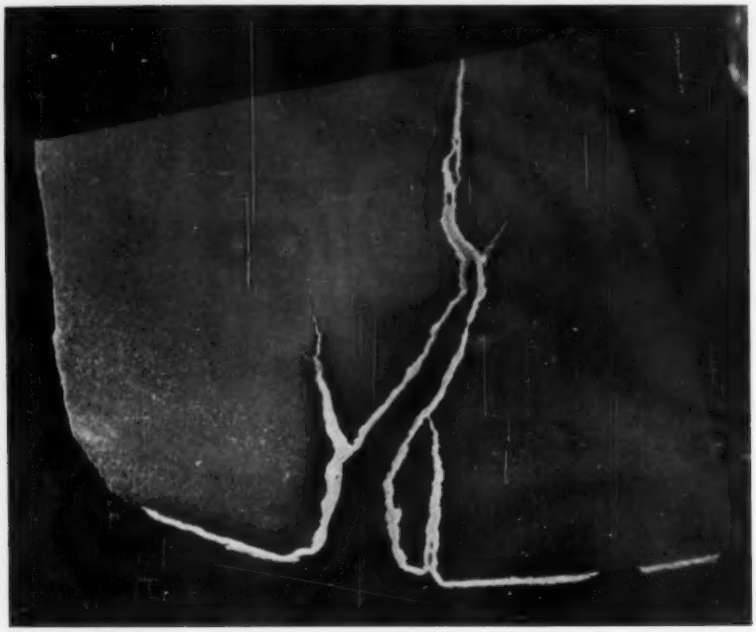


Fig. 1 — Crack on Tension Side of a Steel U-Bend Specimen Caused by Zinc Penetration. Initiated at the throat of a notch in a weld overlay deposit, the crack appeared after the specimen was bent and immersed in zinc at 890° F. It follows an intergranular path. Test demonstrates possible mechanism of weld root failure in galvanized steel weldments. 6 ×, 2% nital

Brittle Fractures in Spheres

K. Masubuchi, Transportation Technical Research Institute, Tokyo, reported on work done in Japan on the problem of brittle fracture of welded structures. Here too the objective was to produce brittle fracture in laboratory specimens designed to approximate the structure conditions of pressure vessels. Test structures were fabricated in the form of spheres almost 5 ft. in diameter. A flat disk — in most tests a mild steel of low notch toughness — 36 in. in diameter was welded in as a part of the sphere wall. After fabrication, a transverse notch, 1½ in. long, was cut into the disk weld joint to act as a crack initiation point.

In the range −25 to 32° F., hydraulic loads applied to the sphere resulted in spontaneous brittle fracture of the disk at stress levels far below the yield stress of the steel. Preloading the sphere above the transition temperature changed the response entirely. Even though tested below the transition temperature, specimens did not rupture until stressed above the preloading stress.

Low-Alloy Steel Weldments

J. T. Berry, Armour Research Foundation, Illinois Institute of Technology, described a technique for investigating cracking in joints of low-alloy arc welded steel. A special chamber was designed so that the test welds could be made in a controlled atmosphere. Most tests were made in hydrogen and argon. The partial pressure of hydrogen was varied and its effect on cracking was studied. It was brought out that cracking seems to occur preferentially at prior austenite grain boundaries and at areas of mixed structure such as in dendritic boundaries of welds and along bands in the base metal. Stress concentration is, of course, a prerequisite for crack formation.

Welding Galvanized Steel

The problem of welding galvanized steel was discussed by J. F. Rudy, Armour Research Foundation. Work was aimed at finding the possible mechanism of cracking in weld roots where a fillet weld joins a plate to the surface of another which is zinc coated. The mechanism seems to be similar to stress-corrosion involving a reaction between solid steel and liquid zinc (Fig. 1) during cooling of the weld. If liquid zinc is available, it will penetrate and weaken the grain boundaries of the solid steel, which is highly stressed during cooling. Zinc penetration into stressed regions starts and propagates the crack until the stress is relieved.

The answer to the problem may be to reduce the stress concentration by rounding the fillet root, to remove the reservoir of liquid zinc at the joining surface, and to deposit a weld metal, *("Spotlight on Welding" continued on p. 162)*

Statistics on Metallurgical Education

*By W. O. PHILBROOK**

Though Bachelor's degrees granted increased by 14.4%, the number of graduates receiving Master's degrees rose only 5% in the school year 1957-58 over the previous year. Doctors totaled 70, a drop of 16%. (A3g)

THE TRENDS in supply of trained metallurgists predicted four years ago by Dr. Bever† have held up remarkably well through 1958, but there are distressing signs of a downturn in the near future. For the school year 1957-58, there were 683 Bachelor's, 185 Master's and 70 Doctor's degrees awarded. These represent an increase over the preceding year of 14.4% for first degrees, but only a 5% gain for Master's and a distressing decrease of 16% in the number of Doctorate degrees. A small measure of encouragement may be taken from the tabulation of first positions taken after graduation. It shows an increase in the proportion of Bachelor's and Master's degree holders going on to graduate work.

In projecting the future trend from the preceding known record of growth, it is necessary to take into account the enrollment figures that have been released by the Office of Education of the U.S. Department of Health, Education and Welfare since our statistics were gathered. The latest data for the fall of 1958 reveal an alarming decrease of 11.1% in freshman enrollment in all engineering subjects, with lesser losses in the sophomore and junior years. Metallurgical engineering classes followed a parallel trend. Thus, it appears that the class of 1958-59, for which statistics are now being gathered, will prove to have been the peak year in Bachelor's degrees. Master's degrees may taper off in a year or two, and Doctor's degrees will probably hold in the 70 to 80 per year range. A reversal of enrollment trends will be necessary if the metallurgical profession is to resume its recent growth rate.

Questionnaires were sent to the 63 schools that grant degrees in metallurgy and metallurgical engineering. Response was such that we feel these data represent 100% coverage. The committee has made a strong effort to assure complete coverage, and to promote accurate reporting not only for its own questionnaire but also to government agencies collecting similar data.

In addition to the totals reported, one Bachelor's degree was granted in Science Engineering and four Master's degrees were awarded in Solid-State Physics. All were metallurgy majors.

The number of foreign students receiving Bachelor's degrees in metallurgy approximately doubled over the preceding year, but changes in advanced degrees awarded to foreign students were hardly significant. They remained in about the same proportion to total degrees.

Information on Schools of Metallurgy

There is a light trend toward larger undergraduate classes compared with the 1956-57 year, but only one-third of the 54 schools granting first degrees had graduating classes larger than 15. Five schools graduated no seniors last year, and 20 had classes of 5 or less. It appears that American schools can absorb many additional students in metallurgy.

Of the 63 schools offering degree courses in metallurgy, 39 provide training from the Bachelor to the Doctorate level, 14 offer the Bachelor's and Master's degree, and 6 confine themselves to undergraduate work only. Only four schools limit their efforts to graduate work, two of these giving both Masters and Doctors, one the Masters

*Professor of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh; Past Chairman, Committee on Metallurgical Statistics, A.S.M. Foundation for Education and Research. Present members of the committee: Morris E. Nicholson, Chairman (University of Minnesota), John P. Nielson (New York University), R. E. Grace (Purdue University), David V. Ragone (University of Michigan).

†"The Supply of Metallurgists With Graduate Training", *Metal Progress*, August 1955, p. 82.

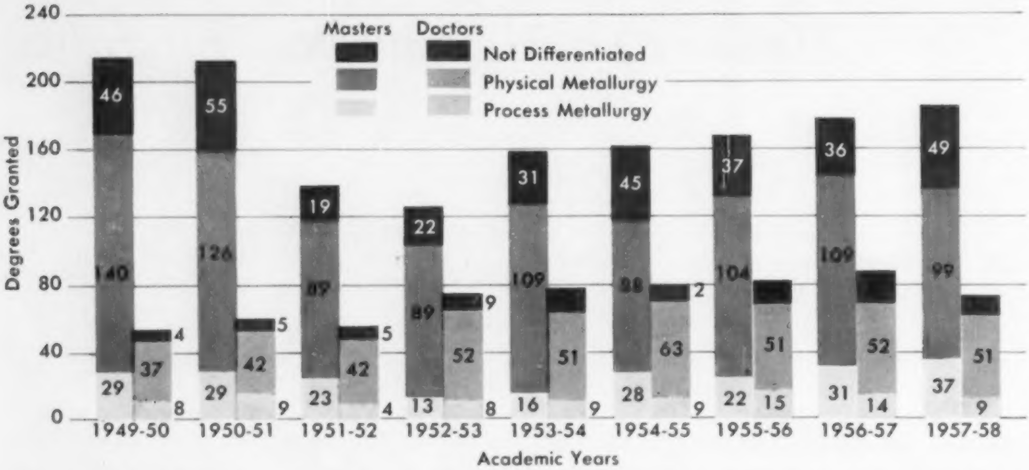


Fig. 1 — Graduate Degrees Granted in Metallurgy in the U.S., 1950 Through 1958. Light color bars represent Master's degrees; darker bars Doctor's

only, and one the Doctors only. These counts are based entirely on questionnaire returns without verification by additional correspondence or reference to catalogues.

As the table shows, there was a decrease of about 10% for both Bachelors and Doctors going into industry. For the Bachelors this was accounted for largely by a 6% increase in the proportion going on to graduate work, and nearly 3% increase in those called to military service. The Doctors lost by industry went into teaching and academic research or research institutes. In the Masters column, there is a small shift in the academic category from teaching and research to graduate student appointments. Considering also the results of an earlier questionnaire for 1954-56 (*Metal Progress*, September 1958, p. 114), there is an apparent four-year trend toward increasing absorption of Masters' holders in government offices and laboratories. On the whole, the four-year trend in all categories seems to be toward increasing interest in scientific and academic work. Industrial research and development show the greatest decline.

In conclusion, the Committee expresses its appreciation for the time and interest of all of those who have contributed to these reports on educational statistics. The work will be carried on for the current academic year under the able chairmanship of Prof. M. E. Nicholson, Jr. Continued cooperation is needed for the Committee to perform its mission of providing authoritative information on trends in metallurgical education for the profession.

First Positions Taken by Students After Graduation

	Bachelors		Masters		Doctors	
	1957-58	1956-57	1957-58	1956-57	1957-58	1956-57
Industry, operations	29.0%	26.8%	13.5%	14.5%	0.0%	0.0%
Research and development	13.3	13.7	28.1	29.1	48.6	59.1
Not differentiated	19.8	31.8	4.9	3.4	1.4	2.4
Total industry	62.1	72.3	46.5	47.0	50.0	61.5
Academic, teaching primarily	0.9	0.2	2.7	4.1	18.6	15.7
Research primarily	0.6	1.1	1.6	2.9	10.0	7.2
Graduate study primarily	18.5	12.9	28.1	25.6	1.4	0.0
Research institutes	0.9	2.5	3.8	2.9	7.1	0.0
Government	3.1	1.8	7.0	4.1	7.1	9.6
Military service	8.8	6.1	3.2	3.5	1.4	2.4
Other or unknown	5.3	3.1	7.0	9.9	4.3	3.6
Total number represented	683	556	185	172	70	83
% of graduates represented	100	93.1	100	97.7	100	100.0

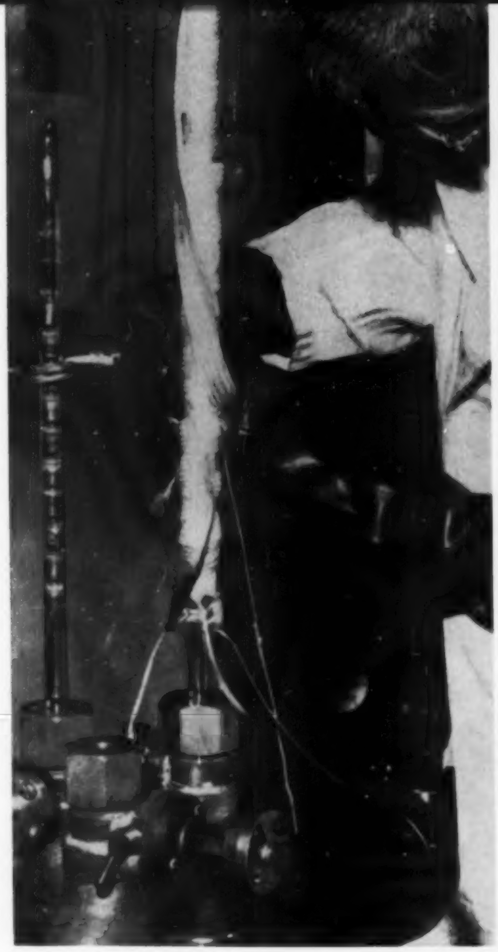


Fig. 1 – Operator Is Vacuum Brazing 15 Canisters Individually With a Small Induction Coil Which Fits Over the Tube. Total brazing time: less than 3 min. Tube at right is being preheated during evacuation of gas

Short Runs

Brazing in Vacuum by Induction Heating

*By RICHARD E. PARET**

BRAZING in vacuum usually gives sound, homogeneous joints in stainless steel parts. With unstabilized austenitic alloys, however, prolonged heating between 800 and 1500° F. during brazing may precipitate carbides at grain boundaries. Precipitation will be reduced if brazing is done with a heating technique which restricts the heat application to the joint to be brazed. Induction coils serve this purpose. Not only do they reduce the area which is heated but they shorten brazing times.

Induction brazing in vacuum is used to join stainless steel caps and shells (Type 302 or 304) to make hermetically sealed canisters. Cap and shell are machined so that there is 0.002 to 0.004-in. clearance between them. Then they are assembled with preformed rings of brazing alloy and stacked one on top of the other in a vacuum tube (see Fig. 1). An asbestos-covered tape heater serves to heat the tube and workpieces to 300° F. while vacuum pumps reduce the pressure in the tube to 0.001 mm. Hg absolute. The joints are brazed by passing the induction coil down the tube exterior, pausing long enough at each joint to melt the filler metal. Each joint requires only 15 to 20 sec. for brazing. Joint strength is 70,000 psi. (shear). Units are also pressure-tight when tested overnight in helium at 15 atmospheres.

*American Iron and Steel Institute, New York.

No Sparking From Beryllium-Copper Trolley Wheels

TINY SPARKS can be dangerous in some industries. To eliminate one source, Saginaw Products Corp., Saginaw, Mich., has developed trolley wheels of nonsparking beryllium copper. They wear as well as steel wheels, and can be used on overhead conveyers or chain hoists installed where explosion hazards exist – paint spray booths, chemical treatment locations, explosive plants and the like.

"Berylco 25" alloy is used only for the outer shell of the wheel; this is exposed to continuous wear from both sides. On the outside, it is subjected to all the abrasive wear that a trolley wheel ordinarily receives, including abrasion from dust particles in the atmosphere. On the inside, wear comes from the moving balls that use the shell as an outer race.

Not only nonsparking, nonmagnetic and corrosion resistant, the alloy also has exceptional physical and mechanical properties:

Tensile strength: 165,000 psi.
Elongation: 5% in 2 in.

Hardness: Rockwell C-36

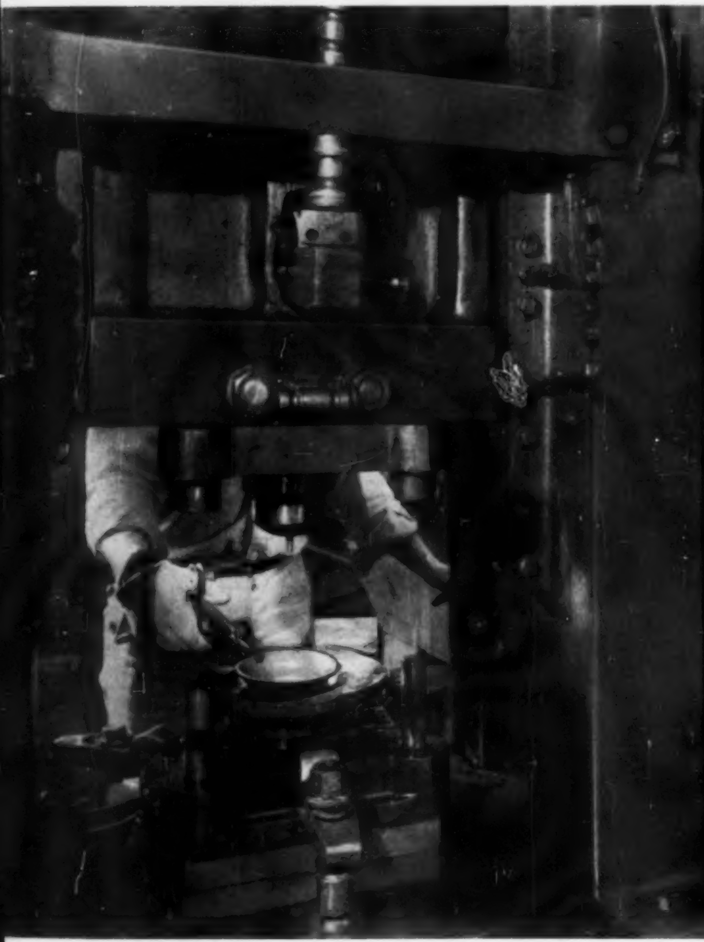
Electrical conductivity: 22% minimum

For fabrication, strip in the solution-annealed condition is purchased in thicknesses of 0.097 and 0.120 in. and in five widths ranging from 5¼ to 7 11/16 in., depending on wheel diameter. Lengths are multiples of the widths.

Alloy parts are processed with basically the same tools used to produce the standard steel trolley wheels. Hardened steel tools in a 60-ton blanking press punch out flat disks from the beryllium-copper strips. A 75-ton press then forms the blanks into a bowl-like shape (see Fig. 1). The depth of the draw is fairly constant, regardless of the disk diameter; it amounts to about 2⅜ in. From four to eight forming steps may be required.

The parts are precipitation hardened after forming by low-temperature heat treatment. At Saginaw, treatment is about 3 hr. in a gas-fired oven at 600° F. Specifications, however, vary from one heat to the next. Following this, shells are cleaned by blasting with G-40 malleable-grade shot.

With the beryllium-copper shell acting as the outer bearing race, a cone of carburized steel serves as the inner race. From 8 to 20 precision balls of high-grade steel are assembled between the two. An insert piece riveted to the outer shell holds cone, balls and a stud in place. The balls are lubricated through a grease fitting in this stud, which fastens the wheel assembly to a counting bracket. Figure 1 shows two stamping operations and a trolley wheel assembly.



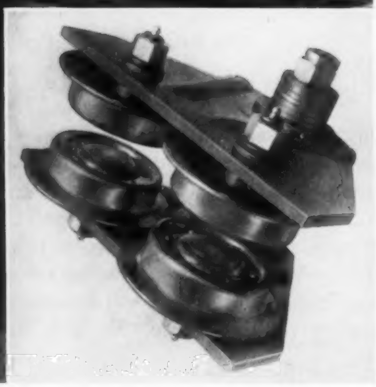


Fig. 1 – The Flat Blank Is Shaped Into a Bowl (Left) by a 75-Ton Press, and Further Formed on a 125-Ton Press (Right). Inset shows completed trolley wheel assembly. (Courtesy Beryllium Corp.)

Correspondence

Ultra High Strength by Austenitic "Cold Working"

PITTSBURGH

In "Austenitic 'Cold Working' for Ultra High Strength", by Messrs. Schmatz, Shyne and Zackay of the Ford Motor Co., the authors state that the method of working steel in the metastable austenitic condition to improve physical properties was first developed by two Dutch investigators, E. M. H. Lips and H. Van Zuilen.

I am rather surprised that the Dutch investigators are credited with this development since the original conception of the interrupted quench and work technique was due to my efforts, beginning in 1950.

The basic method of working steels in the metastable austentitic condition above the M_s temperature to obtain improved physical properties was shown schematically in a diagram included in an article describing my work in *Iron Age*, Dec. 27, 1951, and reproduced in the correspondence section of the February 1955 issue of *Metal Progress*, p. 119. Basically, this diagram illustrates the method which Ford designates as "Ausforming".

RICHARD F. HARVEY

Sorry—Our Mistake!

If our readers were somewhat puzzled after studying Fig. 3 (on p. 149-A) of the November lead digest on "Progress in Explosive Forming", it's understandable. Though the S-N curves shown are accurate in every respect, an important item was inadvertently omitted on each one – the designation of the alloy being tested. The top graph of Fig. 3 is for VascoJet 1000, the middle one for AM 350, the bottom one for an 8% Mn titanium alloy.

Flakes in Steel

LONG BEACH, CALIF.

According to C. E. Sims*, flakes or shatter cracks in steel forgings and castings are caused by hydrogen gas, which evolves within the steel and builds up a pressure high enough to disrupt the steel, and are associated with retained austentite. This phenomenon is very similar to fish-scaling of enameled steel caused by hydrogen gas which evolves at the steel-enamel interface and builds up a pressure high enough to break the enamel.†

In both cases, the effect is localized and the defective spots few and far between. The question then is by what mechanism the hydrogen becomes nonuniformly distributed to this extent. The retained austenite, similarly nonuniformly distributed, is believed to offer a higher solubility to hydrogen than does ferrite, but this does not seem to account for the high concentration of hydrogen required.

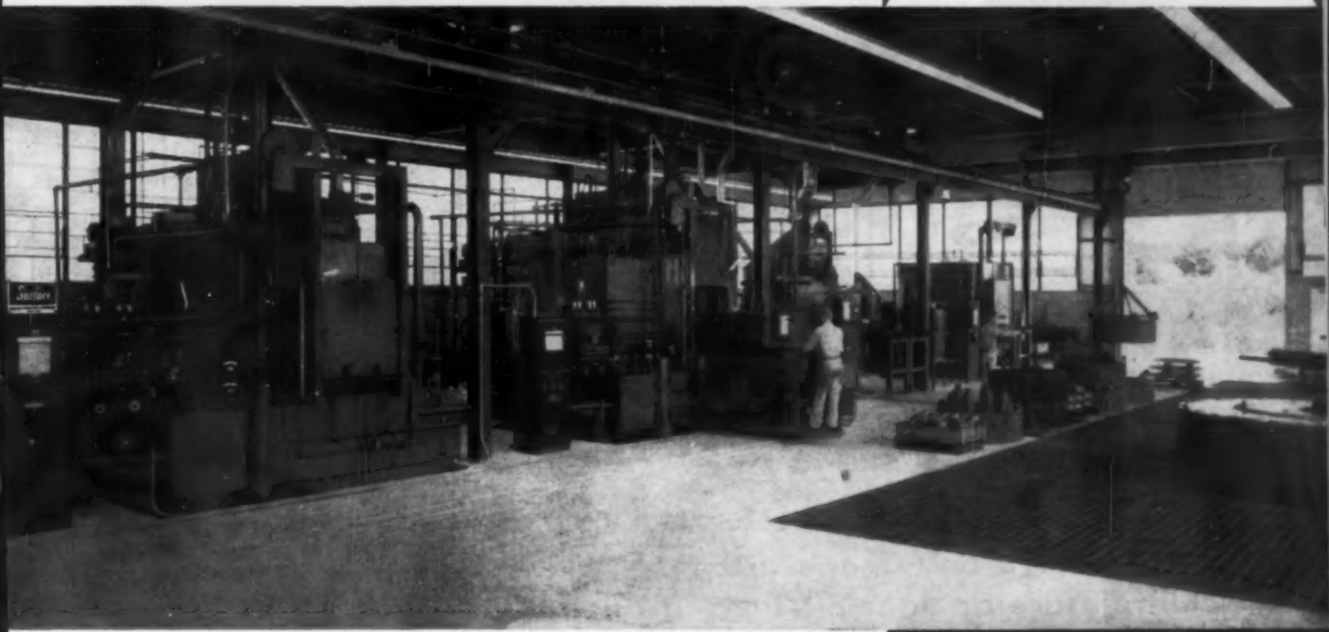
The conversion of austenite into ferrite plus cementite occurs by way of ε-carbide as an intermediate compound.‡ The ε-carbide has been prepared and analyzed. It contains much hydrogen and its composition is probably Fe_2HC. Thus, ε-carbide contains much more hydrogen than does austenite. Consequently, ε-carbide, in its formation from austenite, sucks up hydrogen from the adjacent ferrite in addition to that taken over from the austenite. The hydrogen is then released in the subsequent transformation of ε-carbide into cementite.

T. G. OWE BERG
Materials Research Group
Long Beach Div.
Douglas Aircraft Co., Inc.

*Gases in Metals, American Society for Metals, 1953, p. 119.

†Paper presented by T. G. Owe Berg at the annual meeting of the American Ceramic Society, Chicago, May 1959.

‡L. J. E. Hofer and E. M. Cohn, *Nature*, Vol. 167, 1951, p. 977.


Surface

Tropical Wonder

ROCHESTER, N. Y.

The magic of alloying created the exotic palm, shown below, in the midst of an aluminum-copper-zinc system, representative of one of the zinc-base alloys which is finding

some use in low-temperature soldering of aluminum. At a magnification of 480 diameters, an etchant of chromic acid-sodium sulphate brought this phenomenon into view.

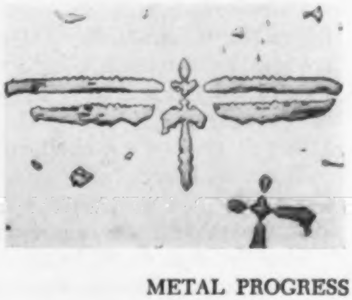
RUSSEL H. BRUSH
Metallurgist
Eastman Kodak Co.

Metallurgical Dragonfly

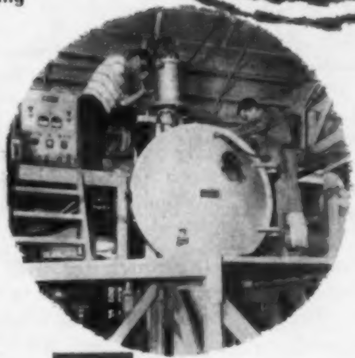
BAYONNE, N. J.

The "metallurgical dragons" which have appeared in the correspondence column of *Metal Progress* are very interesting and unusual. To keep the hunting spirit alive, I would like to offer the enclosed metallurgical dragonfly (below). The micro shows columbium carbides, in an as-cast experimental melt, photographed at 1000 diameters.

NINO S. PITEA
Metallographic Section
Research Laboratory
International Nickel Co.



*One of the advanced techniques at Precision Castparts contributing to ultra performance in investment casting of high strength, high temperature alloys.



The PC vacuum melting and molding system remelts alloys by induction under vacuum of less than 10 microns of mercury. The virtually perfect vacuum excludes atmospheric elements that might affect the chemistry of the melt, and the performance of the casting. Precision Castparts has the only vacuum melting facility for investment casting located in the West.

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DISTRICT STEEL CORP., 5249 Sheila St., Los Angeles 22, Cal. • ANgelus 3-2149

Personal Mention

J. E. Wilson

J. E. Wilson ⊕ has been promoted to manager, advanced chamber materials engineering, rocket engine section, Flight Propulsion Laboratory Dept., of General Electric Co., Evendale, Ohio. His new responsibilities will include development and improvement of all metals used in rocket cases and the metal processes involved. His former position entailed responsibility for the improvement and development of cast high-temperature alloys for jet engine turbine service, and resulted in his development of the DCM alloy (see *Metal Progress*, November 1958).

Mr. Wilson joined General Electric in 1951 after graduation from the University of Cincinnati with a degree in metallurgical engineering. In 1952 he joined the engineering group of the blades manufacturing section and in 1953 established the blades manufacturing metallurgical laboratory. Three years later he transferred from the job of supervisor, metallographic and physical tests, in the process engineering development laboratory to the jet engine department with the prime responsibility of developing new high-temperature turbine blade alloys. While in this position he developed the DCM alloy, developed an alloy for 2130° F. service under a stress level of 3300 psi., and was co-contributor to a reliable statistical design method for the creation of new alloys – resulting in DCM, Cosmoloy and others. In July 1959, he was appointed manager of advanced chamber materials engineering in the rocket engine section.

Laurence E. Poteat ⊕ has been assigned to the faculty of North Carolina State College, Raleigh, N. C., as instructor of metallurgical engineering. For the past three years, he has been associated with Watertown Arsenal Laboratories, Watertown, Mass., and prior to that was employed by the Metals Research Laboratory of Union Carbide Corp., Niagara Falls, N. Y.

Joseph Warman ⊕ is now working on the staff of Hevi Duty Electric Co.'s Watertown, Wis., furnace laboratory, engaged primarily on the development of new atmosphere control equipment.

Madan M. Nanda ⊕ recently joined the Electric Boat Div. of General Dynamics Corp., in Groton, Conn., as a metallurgist in their research and development laboratory. Prior to joining Electric Boat, he worked at Brookhaven National Laboratory.

Thomas F. Moorman ⊕, formerly with Peninsular Steel Co., has joined the staff of the Detroit field section of International Nickel Co., New York. Mr. Moorman will be concerned primarily with the market development of nickel-containing materials.

Edward J. Dolan ⊕ has left his position as assistant metallurgist for Reed & Prince of Worcester, Mass., to accept a post as a senior metallurgist for the Hyatt Bearings Div. of General Motors Corp. in Harrison, N. J.

Harry V. Makar ⊕, after his release from active duty with the Marine Corps in 1958, joined the metallurgical laboratory of the Titusville, Pa., division of Universal Cyclops Steel Corp. He is now working on toolsteel research at the Bridgeville division.

Paul R. Totten ⊕ has been appointed works manager of the Cleveland mill division of Chase Brass & Copper Co. He comes to Chase from the Allenport works of Pittsburgh Steel Co., where he was divisional superintendent for four and a half years.

William J. Parsons ⊕ has been appointed senior vice-president of the industrial division of the Pacific Scientific Co., San Francisco. In his new capacity, his headquarters will continue to be in Los Angeles, where he will supervise and coordinate the industrial division.

Paul Hutchinson ⊕ has been appointed to the staff of Charles F. Hutchinson Advertising Agency in Boston as account executive. He had been associated with Perkin-Elmer Corp. of Norwalk, Conn., as sales director of the instrument division since 1955.

Robert E. Lenhart ⊕ has been appointed supervisor of silicon steels in Crucible Steel Co. of America's central research laboratory. He was formerly manager of alloy development at the Beryllium Corp. in Reading, Pa.

Robert G. Griffith ⊕ has been promoted to superintendent of the seamless tube mills at the Campbell works of the Youngstown Sheet and Tube Co., Youngstown, Ohio. He joined the company in 1958 as a general foreman.

Felix von Gemmingen, Jr., ⊕ is now working in the Fundamental Research Laboratory of U. S. Steel Corp. in Monroeville, Pa., where his primary concern is creep phenomena.

Philip R. Johnson ⊕, a recent graduate of the Missouri School of Mines, is now serving in the U. S. Army.

Jerome V. Bell ⊕ has been elected vice-president of Alloy Surfaces Co., Wilmington, Del. Mr. Bell, who joined the company in 1957 as chief engineer, was formerly manufacturing engineer for the atomic and power equipment department of General Electric Co.

Edwin A. Yeo, Jr., ⊕ has been promoted from district manager in Chicago for Leeds & Northrup Co., Philadelphia, to the new post of assistant manager in the sales division. He has been succeeded as district manager by **Willard H. Neu** ⊕, formerly district manager in Pittsburgh.

Personals . . .

John C. Cassidy ⊕ has been appointed manager of projects for the American Car and Foundry Div. of ACF Industries, Inc., New York. Since joining ACF in 1954, he has been a senior research engineer and more recently project manager.

Eugene A. March ⊕ has been named assistant works manager at Crucible Steel Co. of America's Midland, Pa., plant. He has been succeeded as division superintendent of technical services by **Guy F. McCracken** ⊕, formerly chief control metallurgist at Midland. Mr. March joined Crucible in 1946 as a metallurgist, mill control, at the company's Sanderson-Halcomb Works in Syracuse, N. Y., and was transferred to the Midland works in 1958. Mr. McCracken also joined Crucible's Sanderson-Halcomb Works (in 1949) and was assigned to Midland last January.

Arthur E. Powers ⊕ has joined the staff of the Knolls Atomic Power Laboratory, Schenectady, N. Y., operated by General Electric Co., as a physical metallurgist in the Materials Development Operation. Dr. Powers joined General Electric in 1947 and transferred to the Power Tube Department in 1957.

Michael Zetz ⊕ has been appointed plant manager for the Louisville, Ohio, plant of the Jones & Laughlin Steel Corp.'s Stainless and Strip Div. Mr. Zetz joined J&L as superintendent of quality and production control at the Louisville plant in 1958.

Alexander S. Zello ⊕ has been named chief engineer of Bridgeport Rolling Mills Co., a subsidiary of Atlantic Coast Industries, Inc., Bridgeport, Conn. He was formerly director of engineering of W. S. Rockwell Co. and works engineer at Stamford Rolling Mills Co.

Robert G. Martinek ⊕ has been appointed applications engineer for fuel-fired heat treating furnace equipment for Hevi-Duty Electric Co., a division of Basic Products Corp., Milwaukee. He was formerly chief engineer for Eclipse Fuel Engineering Co. of Canada.

Personals . . .

John A. Succop ⊕, vice-president in charge of metallurgy for Heppenstall Co., Pittsburgh, has retired after 39 years' service with the company; he will continue to serve the company in a consulting capacity. Mr. Succop joined the heat treat department of Heppenstall in 1920 after receiving his metallurgical engineering degree from Pennsylvania State University. He was transferred to the metallurgical department in 1921, appointed chief metallurgical engineer in 1944 and elected a vice-president of the company in 1956.

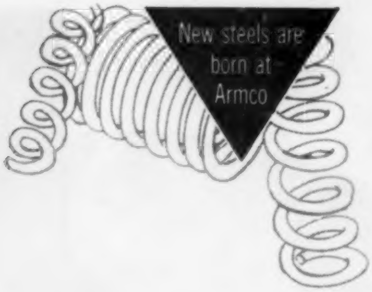
Ernest A. Sticha ⊕ has been named chief research metallurgist by Edward Valves, Inc., a subsidiary of Rockwell Mfg. Co., East Chicago, Ind. He was formerly supervising engineer for Crane Co., Chicago.

Edward L. Roth ⊕, president of Motor Castings Co., West Allis, Wis., has been awarded the Gold Medal of the Gray Iron Founders' Society at the Society's annual meeting in San Francisco recently. Mr. Roth was honored for his many contributions and services to both the Society and industry.

Carleton A. German ⊕ has been elected to the board of directors of Solventol Chemical Products, Inc., Detroit. Mr. German has been connected with the company since 1944 and was recently named general sales manager of all divisions. He has held the positions of sales manager of the industrial division and chief engineer.

G. L. Galmish ⊕, formerly affiliated with the Michigan Malleable Iron Co., Detroit, has accepted a post as metallurgical engineer with the Detroit Aluminum and Brass Co. at the company's Bellefontaine, Ohio, plant.

Loren B. Clay ⊕ has been appointed sales manager of Joseph T. Ryerson and Son, Inc., Houston, Tex. Mr. Clay has been connected with Ryerson since 1940, advancing to his present post from district sales manager at the company's Los Angeles plant.



Advantages of 17-7 PH Stainless Steel For Springs in Severe Service

Excellent elastic properties, strength at high temperatures, resistance to corrosion—all are combined in Armco 17-7 PH Stainless Steel wire to make it an outstanding material for springs operating under severe conditions.

Armco 17-7 PH is one of a family of Armco Precipitation-Hardening Stainless Steels developed to meet the exacting needs of space age technology. For springs it offers a unique combination of properties that make it especially useful in applications involving heat or corrosion, where ordinary spring materials don't hold up.

EXCELLENT ELASTIC PROPERTIES

In tension, the elastic limit of 17-7 PH wire is approximately 75% of ultimate tensile strength; in torsion, about 55%. The figures in Table 1 give an idea of the excellence of these values. See table 2 for a comparison with 18-8 stainless and music wire. Relaxation and torsional modulus values of 17-7 PH stainless hold at high levels even at temperatures up to about 650 F.

TABLE 1
Typical Room Temperature Properties of .052 to .061-inch 17-7 PH Wire

CONDITION	PROPERTIES			
	UTS, psi	0.2% Yld. Str., psi	Elong. in 2", %	Fatigue Str. * % of Tens. Str. at 10^7 Cycles
C	250-280,000	230-260,000	—	—
CH 900	305-335,000	285-315,000	2-4	36

*Machined and polished surfaces

TABLE 2
Comparison of Typical Mechanical Properties of Armco 17-7 PH Condition CH 900 Wire, 18-8 Spring Wire and Music Wire

	17-7 PH	18-8	MUSIC WIRE
Diameter, Inches	Ultimate Tensile Strength, 1000 psi		
.030	320-350	280-310	340-365
.093	279-309	230-260	285-305
.148	256-286	201-231	263-280
.192	252-282	185-215	252-267
Diameter, Inches	Max. Torsional Stress When Closed Solid, 1000 psi		
.050	170	113	160
.100	160	100	140
.150	155	93	130
.200	150	87	—

CORROSION RESISTANCE

Armco 17-7 PH Stainless Steel extends the dependability of springs beyond that of metals with comparable strength but inferior resistance to corrosion. In Condition CH 900, for example, the condition most widely used for wire products, 17-7 PH resists corrosion as well as 18-8 full-hard temper stainless steel. Even in a marine atmosphere, 2 years' exposure produces only superficial rusting.

SPRING FABRICATION

Availability of 17-7 PH round or flat wire, coils or straight lengths, and a wide range of sizes and conditions, makes it adaptable to the production of a great many kinds of springs.

It's workable as well. In Conditions C and CH 900, for example, 17-7 PH wire can be wrapped on its own diameter. However, because Condition C is more ductile, it is preferred for spring coiling, especially on automatic machines.

The low-temperature precipitation hardening of 17-7 PH after fabrication takes care of stress relieving too. No further heat treatment is required as with other hardenable spring materials. Thus a production operation is eliminated and the possibility of dimensional changes is avoided. Also, because no heavy scale is produced and because plating is not necessary, 17-7 PH springs are not exposed to hydrogen-absorbing conditions. A very light pickle will remove heat tint.

SEND COUPON FOR DATA

For more information on Armco 17-7 PH Stainless Steel or its special precipitation hardening companion grades, 17-4 PH and PH 15-7 Mo, just fill in and mail the coupon. There's no obligation.

ARMCO STEEL CORPORATION
3099 Curtis Street, Middletown, Ohio

Please send more data on:
☐ 17-7 PH ☐ 17-4 PH ☐ PH 15-7 Mo

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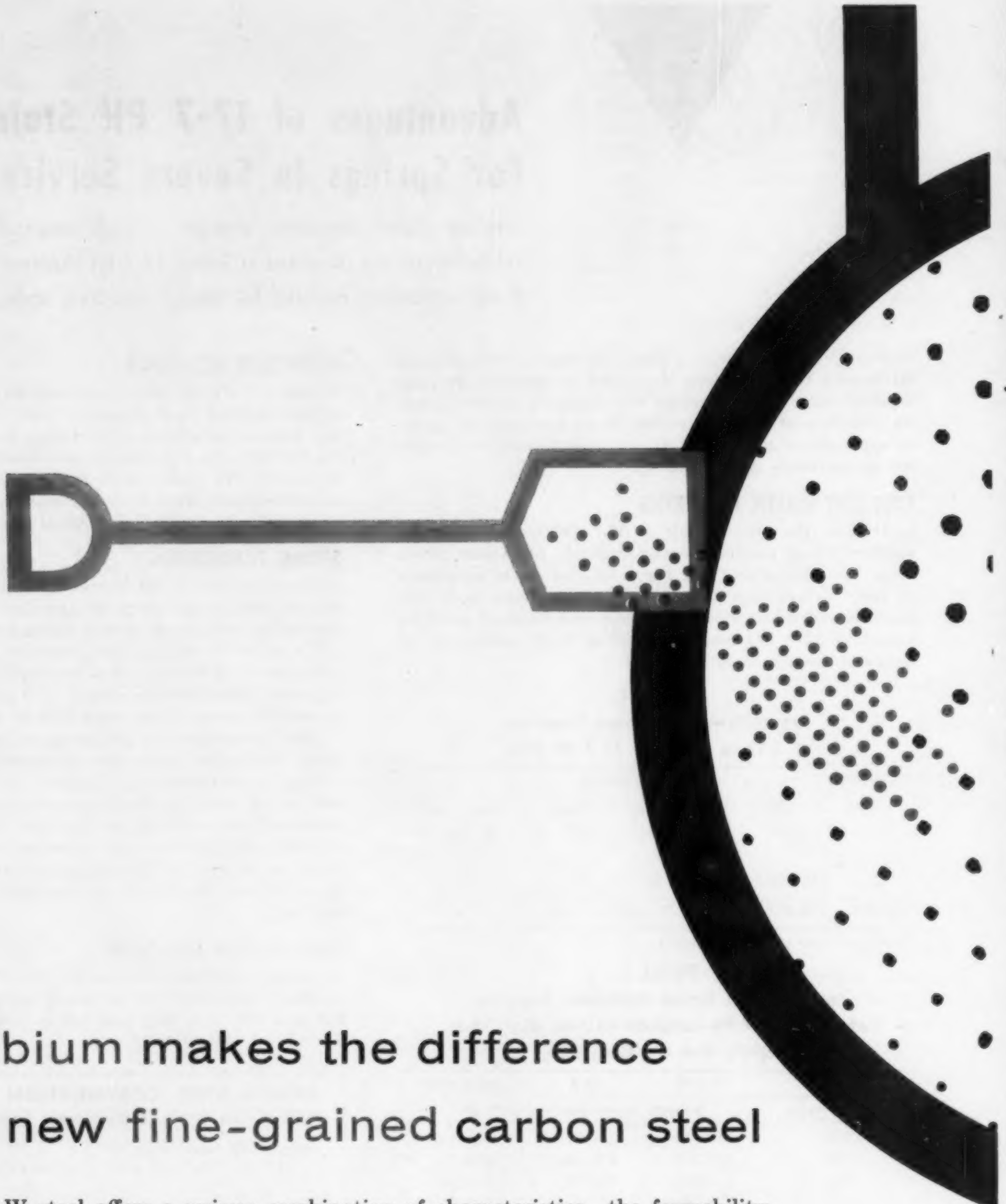
ARMCO STEEL

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation



Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Machining Hard Alloys

Digest of "The Machining of Ultra Strength Alloys", by John Maranchik, Jr., J. V. Gould and P. R. Arzt. Paper presented at the S.A.E. National Aeronautical Meeting, New York, April 1959.

ULTRA-HIGH-STRENGTH alloys are being used more and more for airframe, missile and engine components. Since many of these alloys are new to industry, the machining information available is meager. For materials such as the martensitic low-alloy steels, hot work die steels and martensitic stainless steels, machining data are also lacking. As a result, a research program to evaluate the machining characteristics of these materials has been started. The work (sponsored by the Air Force) is being performed by Metcut Research Associates Inc. The article gives 32 figures of tool life curves (not given here) and summaries of machining data (see Data Sheet, p. 96-B).

Turning proved to be least difficult of the various types of machining operations. Reasonable tool life could be obtained without resorting to unusual types of tools, tool geometries, or techniques. The following general recommendations apply:

1. Use a rigid machine and strong, solid tools and fixtures.

2. Use the proper type of carbide. For a given type of carbide, select the hardest grade that will perform without chipping.

3. Use cutting speeds, feeds and tool geometries selected from turning data obtained under controlled cutting conditions. The Data Sheet lists recommended carbide grades, tool geometries, cutting speeds and feeds for the alloys mentioned.

In face milling tests on A.I.S.I. 4340 (heat treated to Rockwell C-52), optimum cutter geometry and tool angles were studied. A series of tests was run in which the angle of inclination was kept constant while the resultant rake was varied. Then, rake was held constant and the angle of inclination was varied. A rake of negative 10° and an angle of inclination of 10° (tool geometry: axial angle 0°; radial rake −15°; corner angle 45°) provided consistently good tool life.

Tool life is given in inches of work travel, with the end point being taken as 0.016 in. uniform wear on the peripheral flank of the cutter tooth, or localized tooth breakdown, whichever occurred first. A 2 in. width of cut and 0.100 in. depth of cut was kept constant for all face milling tests. Studies indicated that a feed of 0.005 in. per tooth was best.

Cutter runout becomes a very critical factor in tool life. With a total cutter runout of 0.003 in., tool life was lowered by about 25%, and localized wear developed. With a total runout of 0.005 in., tool life was reduced by some 65%, and severe localized wear caused cutter breakdown.

The best tool geometry for face milling VascoJet 1000 (heat treated to Rockwell C-50) was the same as that for face milling 4340 steel. Carbide evaluation proved that a C-2 grade produced considerably better tool life than a C-6 grade. Feed of 0.005 in. per tooth was best for this alloy. At higher feed rates (from 0.010 to 0.015 in. per tooth) localized, rather than uniform, wear occurs.

Side milling tests were made, using a 7 in. diameter inserted tooth face mill, on A.I.S.I. 4340 heat treated to Rockwell C-52. With a *single* tooth in the cutter, best results could be obtained when up milling, using a C-6 cutter with −5° axial rake and −10° radial rake. Tool life was 72 in. work travel when milling at a cutting speed of 145 ft. per min. and a feed of 0.0075 in. per tooth. When down milling, teeth chipped badly and tool life was only 20 in. work travel. Down milling was best when using a C-2 grade; however, maximum tool life was only 50% of that obtained from up milling with a C-6 tool.

For side milling VascoJet 1000 at Rockwell C-52, down milling with a C-2 tool gave best results. At a cutting speed of 145 ft. per min. and 0.0075 in. per tooth feed, a cut of 90 in. was obtained with a single tooth cutter with 0° axial rake and −15° radial rake. Up milling caused almost immediate cutter breakdown.

Though good tool life was obtained at Rockwell C-49 to 50, it decreased rapidly as hardness increased to Rockwell C-52. Above Rockwell C-52, the material was, for all practical purposes, unmachinable with the high speed steel end mills used in the tests. Feeds between 0.001 and 0.0015 in. per tooth must be used to attain a reasonable tool life in end milling 4340 steel at Rockwell C-49.

For end milling 4340 at Rockwell C-52, carbide-tipped cutters were used. Initial tests were all made with standard 1¼ in. diameter, four-tooth carbide-tipped end mills having 1 in. diameter shanks, 1¼ in. flute length and over-all length of 4¼ in. Con-

siderable cutter deflection and resultant poor life was observed. To increase rigidity, special end mills were made with a shank diameter of 1¼ in., and the flute length cut down to ¾ in. These were used in all subsequent tests.

A C-2 grade carbide provided six times better tool life than a C-6 grade. In addition, C-2 grade teeth wore evenly and did not chip. Cutting fluids are required for maximum tool life in end milling. When sprayed as a mist through the cutter, an appreciable increase in tool life was obtained. The mist was fed through a hollow draw bolt through the cutter to the tool work interface.

Since tool life for end milling VascoJet 1000 at Rockwell C-52 with high speed cutters was extremely poor, all subsequent tests were made with carbide-tipped tools. A C-2 grade and a mist coolant applied through the cutter yielded the best results. A 0° axial rake and 0° radial rake were best. Positive and negative rake angles caused chatter and low tool life.

Maximum tool life was 105 in. work travel at 60 ft. per min. and 0.0015 in. per tooth feed. At lower speeds, chatter and tooth chippage occurred. Tool life decreased slowly with increasing speed.

Slot milling tests were made on 4340 and VascoJet 1000 steels quenched and tempered to Rockwell C-52. A slot 0.250 in. deep by 1 in. wide was milled by a Cincinnati No. 6 high power horizontal mill. For maximum rigidity, a 2-in. diameter arbor was used and the slotting cutter kept as close to the spindle nose as possible. Overhang of the overarm was kept at a minimum. Tool life was recorded as the inches of work travel before cutter breakdown. Nonferrous C-2 grades were four times better for slot milling than C-6 grades. The C-2 carbide also wore uniformly along the cutting edge, while the C-6 grade fractured and chipped very badly.

A combination of bi-negative 5° axial and negative 10° radial rake produced the highest tool life. The tooth face was ground to 5° axial rake on both corners of the tip. Thus, the cutting edge face shows a wedge shape.

Down milling shows a 3 to 1 im-

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Machining . . .

provement in tool life over up milling in slotting. With conventional milling, there was much vibration even when light feeds were used.

Drilling tests were performed on four ultra strength alloys: 4340, VascoJet 1000, AM 350 and A-286. Those made on 4340 steel with hardnesses of Rockwell C-50 to 55 demonstrated that tool life depended largely on workpiece hardness. With a ¼-in. diameter T-15 drill, a cutting speed of 30 ft. per min. and a feed of 0.001 in. per rev., drill life was 100 holes at Rockwell C-50, 30 holes at Rockwell C-52, and only 5 holes at Rockwell C-55. For maximum drill life, it is extremely important to keep drill length at a minimum. The entire drilling setup must also be rigid as possible. A drill life of 107 holes was obtained in drilling AM 350 (Rockwell C-47) using a T-15 drill with a crankshaft point, a cutting speed of 20 ft. per min., a feed of 0.002 in. per rev. and a highly sulphurized oil.

A good tap life of 146 holes was obtained in tapping 4340 (Rockwell C-50) using standard M-10 four-flute taper tap, a highly chlorinated oil, a cutting speed of 5 ft. per min. and 60% thread. However, for the same cutting conditions, tap life decreased to 18 holes for a 70% thread, and only 13 holes for a 75% thread. Tapping harder 4340 steel (Rockwell C-52) was considerably more difficult. With a standard M-10, four-flute taper tap, a cutting speed of 5 ft. per min. and 60% thread, the best tap life obtained with any commercial cutting fluid tried was only eight holes. The use of inhibited 1, 1, 1 trichloroethane as a cutting fluid resulted in an outstanding increase in tap life to 75 holes.

However, this fluid is volatile and toxic. The maximum allowable concentration in air is 500 ppm, (as compared to 25 ppm. of carbon tetrachloride). Tap life may be further improved by nitriding the tap.

A good tap life of 101 holes was obtained in tapping AM 350 (Rockwell C-47) using a standard M-10, four-flute taper tap, a cutting speed of 9 ft. per min., 75% thread, and a cutting fluid made up of 3 parts of highly chlorinated oil and one part of 1, 1, 1 inhibited trichloroethane.

C.R.W.

Steels for Missiles

Digest of Charles M. Schwab Memorial Lecture by Wernher von Braun, U. S. Army Ordnance Missile Command, Redstone Arsenal, Ala. Address presented at the 67th General Meeting of the American Iron and Steel Institute, New York, May 1959.

MATERIALS for tomorrow's missile designs will depend upon the ingenuity of the materials researcher working with ferrous and nonferrous metals. Usually, the designer looks first at the strength-to-weight ratio. For lightweight booster components, which are required to operate under ambient or low temperatures, high-strength nonferrous materials generally are used because of their excellent strength-to-weight ratios.

Ferrous metals have a major advantage where elevated temperatures and high internal pressure are involved. For example, solid propellant motor cases are manufactured from steel in almost all instances. One reason is that with small rockets the weight of the case is not quite as critical as in the bigger missiles. Another reason is the high pressures and elevated temperatures characteristic of the solid fuel rocket which gives a definite edge to high strength steel for casings. Some steels presently used, or being considered, for motor case applications and their maximum yield strength are:

Material	Maximum Yield Strength
VascoJet 1000	250,000 psi.
Peerless 56	250,000
Tricent	240,000
17-7 PH	220,000
4130	180,000
4340	220,000
PH 15-7 Mo	235,000
USS-X-200	240,000

Higher Strength Needed – Even the strength-to-weight ratios of these materials are not adequate for current propellants. It is expected that higher energy propellants will be developed and these will require metals with higher strength-to-weight ratios. For the Redstone missile system, a low-alloy high-strength steel, MIL-S-7809 (Corten), was employed for the skin of the nose cone and the attached instrument compartment due to the elevated skin temperatures encountered during re-entry and dive through the atmosphere.

Steels for Missiles . . .

Other missile components usually made of steel, include the following:

1. Valve parts.
2. Plumbing and ducting.
3. High-pressure air bottles. (S.A.E. 4130 is most commonly used.)
4. Thrust chamber and nozzles.
5. Heat radiation shields to protect the missile tail.
6. Fire walls.
7. Missile ground support equipment including the fuel and oxidizer trucks, instrument vans, personnel carriers and flame deflectors.
8. Finally, the manufacturing tools required to form, and shape and assemble components and the complete system.

Space Vehicles – Turning to vehicles designed especially for outer space penetrations, additional demands confront the metals engineer and designer. For example, materials are needed which will be resistant to the adverse conditions of the space environment. They include extremes of temperature, high vacuum, solar radiation, cosmic radiation, residual gases and meteoric bombardment. New concepts will be required to develop alloys to cope with these problem areas.

The conditions which will be encountered in outer space present the materials engineer with a new set of problems. One major source of difficulty has been the lack of information on exactly how serious the environmental conditions may be. The gaps are being filled in with data from satellites, space probes and high sounding rockets but a great deal more accurate information will be needed. How this affects the materials picture may be indicated by the cosmic radiation phenomenon. In this case, the integrated effects of radiation on pure metals should approach a saturation state and be comparable to cold working the metal.

Radiation Effects – In alloys, disordering of the desired structure and precipitation hardening can occur if radiation takes place below the annealing temperature. None of these effects should affect the usefulness of metals as structural members. However, it is possible that metals under stress might undergo creep from the effects of radiation-

Steels for Missiles . . .

agitated atoms. Also, the corrosion rate may be affected. Laboratory experiments along these lines are limited largely to radiation of very low particle weight, although we are aware that the more damaging cosmic radiation will occur from high speed heavy particles.

Another area of great interest is the thermal properties of materials under influence of extreme cold to which all shaded areas are exposed in outer space and the high heat flux encountered during re-entry conditions. This is another aspect of material technology where the literature offers little aid. An example is the fact that although tungsten is widely used for high-temperature applications, little is known concerning its thermal properties at high temperatures.

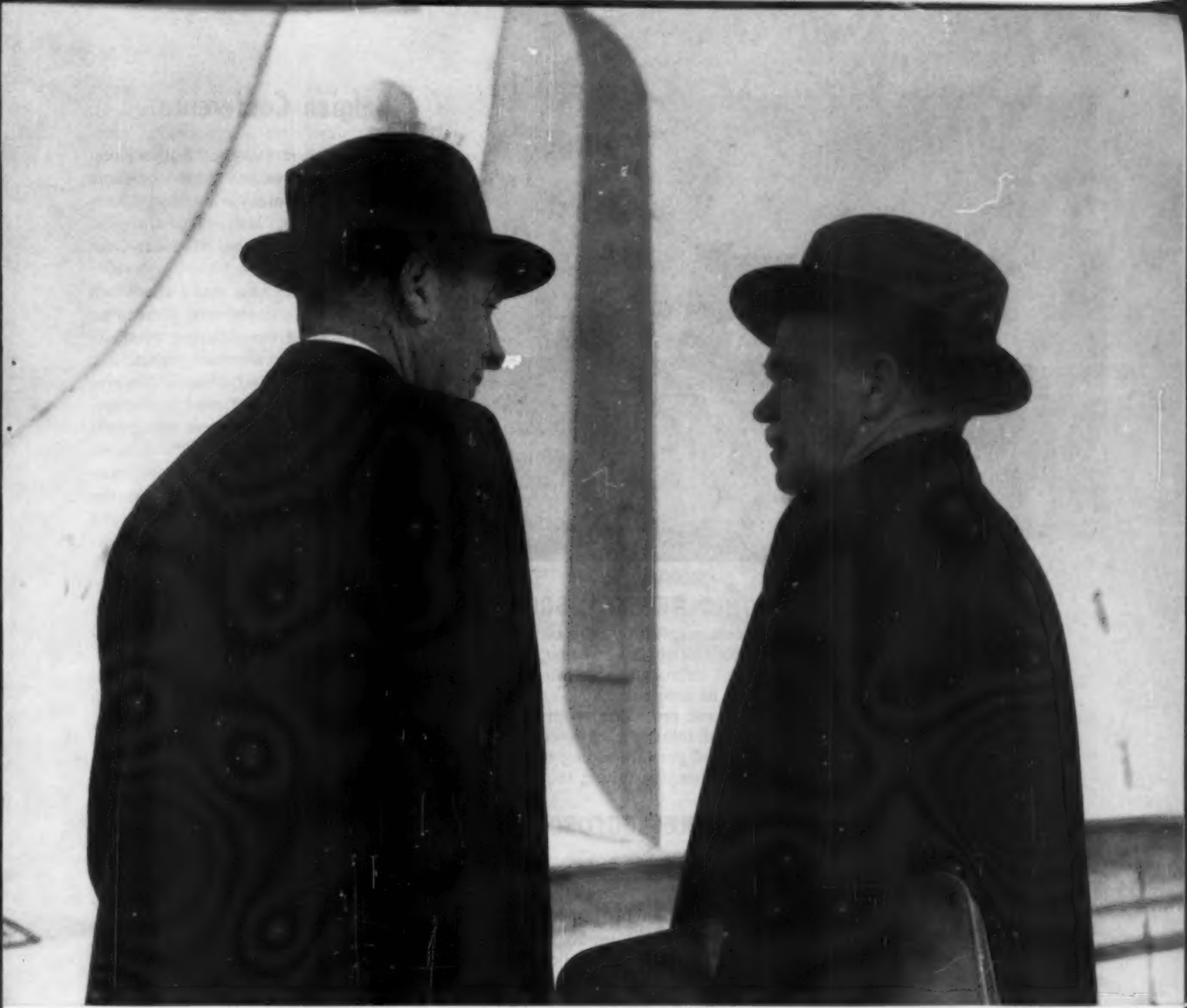
Fabrication – It is well to keep in mind that we must have useful materials; they must not only meet the physical demands in terms of such properties as stress, weight and fatigue resistance, but they must also be amenable to fabrication of rocket systems and their payloads. The requirement is for materials which can be formed into various shapes and welded to provide pressure vessels. We cannot design functional missiles, satellites and space vehicles on the basis of properties of laboratory curiosities. They are simply not applicable in the major projects which will engage our attention as we move ahead.

A.G.G.

Conference in Belgium

Digest of "International Metallurgical Meeting in Belgium", the proceedings of the 1958 International Metallurgical Meeting held in Brussels, Belgium.

PROCEEDINGS of the 1958 International Metallurgical Meeting in Brussels have been published in a single volume. There are about 35 papers, covering practically all the known methods of producing iron and steel. Much of the subject matter was also discussed very thoroughly at the Second World Metallurgical Congress in Chicago in October 1957. The volume contains papers written in English, French,



Belgian Conference . . .

German and Italian. Authors and discussants came from Belgium, France, Germany, England, Sweden, Austria, Italy, Japan, India, Formosa, the United States and the U.S.S.R.

Since Europeans make about half their steel in converters, there were ten papers from different countries describing converter operations. The Belgians and French describe the manufacture of steel in bottom-blown basic converters using enriched air of about 30% oxygen. The use of iron ore in basic converters, oxygen and steam in the final stages of the blow, and oxygen with powdered lime added for desulphurization were also discussed. Steel made by these various processes was low in nitrogen (under 0.005%) and no higher in oxygen or hydrogen than openhearth steel.

The Germans compared the L-D process, the bottom-blown basic bessemer process with 32% oxygen, oxygen steam blowing, and blowing with ordinary air. In an Austrian paper, the method for processing pig iron containing 0.5 to 1.5% P was described. The top-blown oxygen converter does not appear too successful when the phosphorus content is about 0.5%, due to the large slag volume. However, higher phosphorus pig irons were successfully blown in the oxygen converter by using two slags. The first slag was skimmed, and the second used for the first part of the next heat. After the slag was added, blowing continued for 10 min. with oxygen. Then fine ore was added and the slag skimmed. Fresh lime was added since the phosphorus content was below 0.40% at this stage. To hold the second slag in the converter after dephosphorization was complete, the steel was poured through an opening in the side wall under the slag. This left the second slag in the converter for the next heat.

The Kaldo process, which was operated in Sweden in 20-ton vessels, was again described by Bo Kalling. In this process, a converter, tilted at about 20° to the horizontal and rotated slowly, is blown with pure oxygen. A thorough mixing of the slag and the metal is thus obtained. If high-phosphorus iron is processed, two or three slag-offs are made the

same way as in the L-D process.

The Germans also described the rotor steel works at Oberhausen. There a horizontal vessel of about 100-ton capacity is blown with two oxygen jets, one above the bath and the other beneath the bath, while the cylinder is slowly rotated. This operation works very much like the Kaldo process. (All of the vessels described here are lined with basic refractory.)

The Russians had an interesting paper describing the casting of converter steel in a vacuum. It showed how the oxygen, hydrogen and nitrogen were reduced on both rimming steel and killed steel with this operation.

Seven papers described openhearth operations. They covered such items as oxygen-enriched air for combustion, blowing of pure oxygen into the openhearth bath for decarburization, and the all-basic openhearth. A particularly fine paper describing openhearth processes in the United States was given by Max Lightner and David McBride of United States Steel Corp. Several of these papers discussed different types of basic refractories.

There was a lot of discussion of the all-basic openhearth. The use of oxygen for decarburization has caused a temperature rise in the openhearth above 1650° C. (3000° F.). Sometimes temperatures reached 1800° C. (3270° F.). Under these conditions, the old silica roofs are inadequate because this refractory melts at about 1650° C. (3000° F.). About half of the openhearth furnaces in Russia and Germany and over 100 of the 900 furnaces in the United States have basic roofs. The life of the basic roof seems to be two or three times that of a silica roof. However, since the basic refractories cost a lot more than silica, this additional cost must be offset by increased production per hour and fuel savings per ton of steel made. In the United States, these savings have been accomplished since several steel companies are producing steel in openhearth furnaces at a rate of 50 tons per hr. compared to the old rate without oxygen of 15 to 20 tons per hr.

Two papers on electric furnace steel production described the use of oxygen with hot metal. They also emphasized that electric furnaces are more economical than any

Belgian Conference . . .

other for melting an all-scrap charge. The very large furnaces which are now being built vary from 100 to 200 tons in capacity and are very economical when melting cold charges.

A very long paper was given on the experimental low-shaft blast furnace. Results obtained with this furnace were apparently uneconomical, and it is obvious that there will not be much application. The Swedish and English discussants of this paper pointed out that a low-shaft blast furnace is only a small model of a large modern blast furnace. Production per man hour is small compared to the larger furnaces. Anticipated advantages of the low-shaft blast furnace are in processing fine ores and use of fine coke from coal. Troubles with fines have been largely overcome in large furnaces by sintering and by screening out fines from the charge.

All the various processes for the direct reduction of iron ore were described by P. E. Cavanagh of Canada and Antonio Scortecci of Italy. At least 12 different methods for reducing iron ore by direct reduction were discussed. Of the multiplicity of processes described, it seems apparent that the R-N, the H-iron and the Krupp-Renn process are all in commercial operation. Finally, the sponge iron plant in Sweden, such as the Hoganas method and the Wiberg-Soderfors shaft furnace, are also being used commercially now.

There were two papers describing the various operations of modern blast-furnace techniques. In these, the preparation of the ore, use of all-sintered charge, use of higher blast temperatures, use of oxygen and steam in the blast and use of high pressure in the furnace were described. Papers by Americans, Russians, Britons and Belgians were presented on these subjects.

Finally, there were ten papers on the continuous casting of steel, all of which were routine and have been thoroughly described elsewhere.

One interesting factor of the volume is that every paper has a complete bibliography of references and these might be very valuable to anyone investigating any of the operations discussed.

E. C. Wright

Memo on Metals

New Age-hardenable Titanium Alloys Offer Up to 220,000 psi Tensile Strength and Easier Formability for 600 to 1,000 F Applications

Three new age-hardenable titanium alloys may prove to be the solution to many of the strength-weight and temperature problems encountered in designing advanced aircraft and missiles. They may also prove extremely economical for such applications.

All three offer much higher strengths than other titanium alloys — and have the light weight and corrosion resistance typical of titanium alloys. Furthermore, they are readily FORMAGEABLE* — capable of being formed in the solution-treated or "soft" condition and then strengthened by simple thermal aging techniques. Each is now in pilot production and available in limited quantities of mill products.

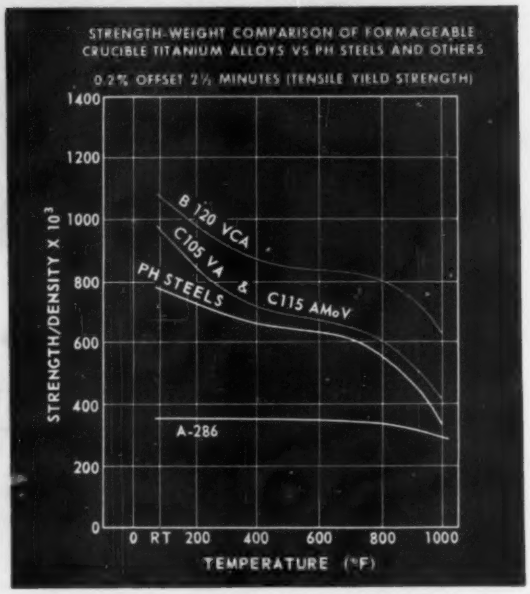
First Age-hardenable All-beta Ti Alloy

Crucible B-120VCA is the first useful titanium alloy with an all-beta (high temperature) structure. It has both the highest strength and best formability of any titanium-base alloy.

This alloy's composition (13%V-11%Cr-3%Al) enables its structure to stay all-beta during forming and/or during slow cooling, and to age to high strength levels at temperatures where distortion is not a problem.

B-120VCA has a unique combination of properties. Room temperature strengths of 200,000 to 250,000 psi have been obtained. On a strength-weight basis this is the highest strength of any available structural material. In short-time elevated temperature tensile tests (1-2 minutes), it offers a decided strength-weight advantage over alternate materials at temperatures up to at least 1,000 F. Under creep conditions, for very long periods of time, it enjoys a strength-weight advantage up to at least 600 F. Beyond this limit, the other Crucible FORMAGEABLE titanium alloys are recommended.

B-120VCA is ductile-weldable, cold-headable, and has great and deep hardenability. Because of this formability, it should prove suitable for applications such as aircraft skins, stiffeners and other primary structural shapes, and for missile pressure tanks, rocket motor cases and structural members. Preliminary tests indicate it may prove unequalled as a construction material for honeycomb assemblies. Because it is so easy to cold-head, it has a large potential in such items as rivets.

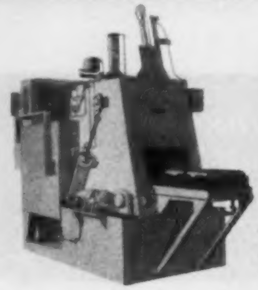


Alpha-beta Titanium-base Alloys

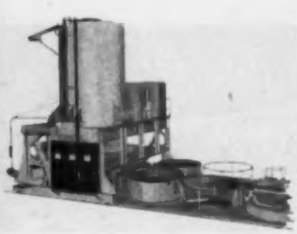
Crucible C-105VA is an alph-beta titanium-base material which also is FORMAGEABLE. Its 16% vanadium content stabilizes a sufficient amount of the beta phase for good age-hardenable response; the 2.5% Al content improves the alloy's elevated temperature properties.

C-105VA resolves two conflicting requirements for aircraft sheet material. It is soft, ductile and easily formed in the solution-quenched condition. Because the formed parts can be aged subsequently at moderate temperatures, parts made of C-105VA can possess high strengths at temperatures up to 800 F for long periods of time.

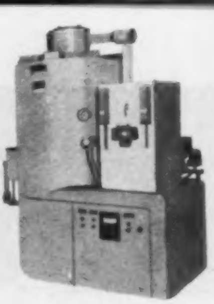
Laboratory Equipment: One-unit box furnace (shown), muffle or for non-oxidizing atmosphere with temperature range to 3000° F.



Automatic Carbonitriding Furnaces: Automated integral quench type (shown) with CORRTHERM electric elements.



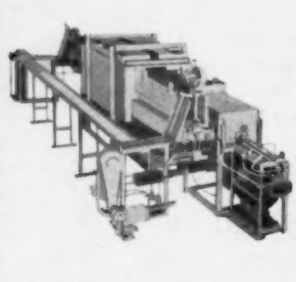
Gantry Type Furnaces: Vertical, controlled-atmosphere, drop bottom, hardening furnace (shown). Complete installation field-installed by Lindberg.



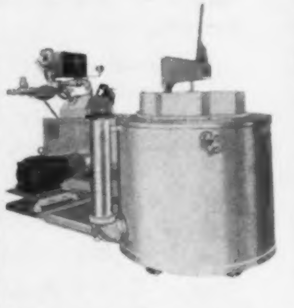
Atmosphere Generators: Hyen generator (shown) for endothermic atmospheres. Generators for all required atmospheres.

Melting and Holding Furnaces: Electric resistance furnace (shown) with capacities of 750 lbs. to 1500 lbs.

Aluminum Reverberatory Furnaces: Twin-chamber melting and holding furnace (shown) with 45,000 lbs. capacity.



Ceramic Kilns: Fully automatic, atmosphere controlled kiln (shown) has 5 control zones for flexibility. Maximum temperature, 2700° F.



Cyclone Tempering Furnaces: Batch type fuel fired tempering furnace (shown). Famous in metal treating industry for years.

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Applying heat to industry has been our only vocation for many years. When your product needs heat it makes sense to consult the most widely experienced experts you can find. We believe we have them here at Lindberg. First of all, we manufacture a full line of equipment, the most complete in the field; heat treating furnaces, salt bath furnaces, melting furnaces, induction heating units, ceramic kilns, laboratory and pilot plant furnaces—electric or fuel fired, built in our plant or field installed. So, we can recommend just the correct techniques best suited to your individual requirements and your production methods. Here at Lindberg we have an exceptionally creative group of metallurgists, research technicians and engineers, the best in the business, we vow. You can count on them to answer your industrial heating problems satisfactorily, no matter how complex or unusual. Our world-wide organization with plants and subsidiary companies in many countries, makes this superior service available to you anywhere.

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CANADA Birlefco-Lindberg, Ltd. Toronto

WEST GERMANY Benno Schilde Maschinenbau AG Bad Hersfeld

JAPAN Lindberg Japan Engineering Co., Ltd. Tokyo

FRANCE Etablissements Jean Aubé Paris

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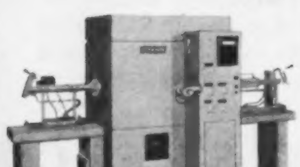
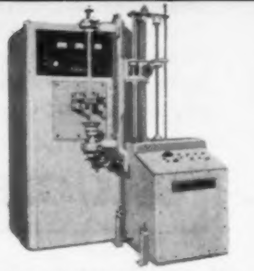
ENGLAND Electric Resistance Furnace Company, Ltd. Weybridge, Surrey

SWITZERLAND Elco-Industrieofen A.G. Basel

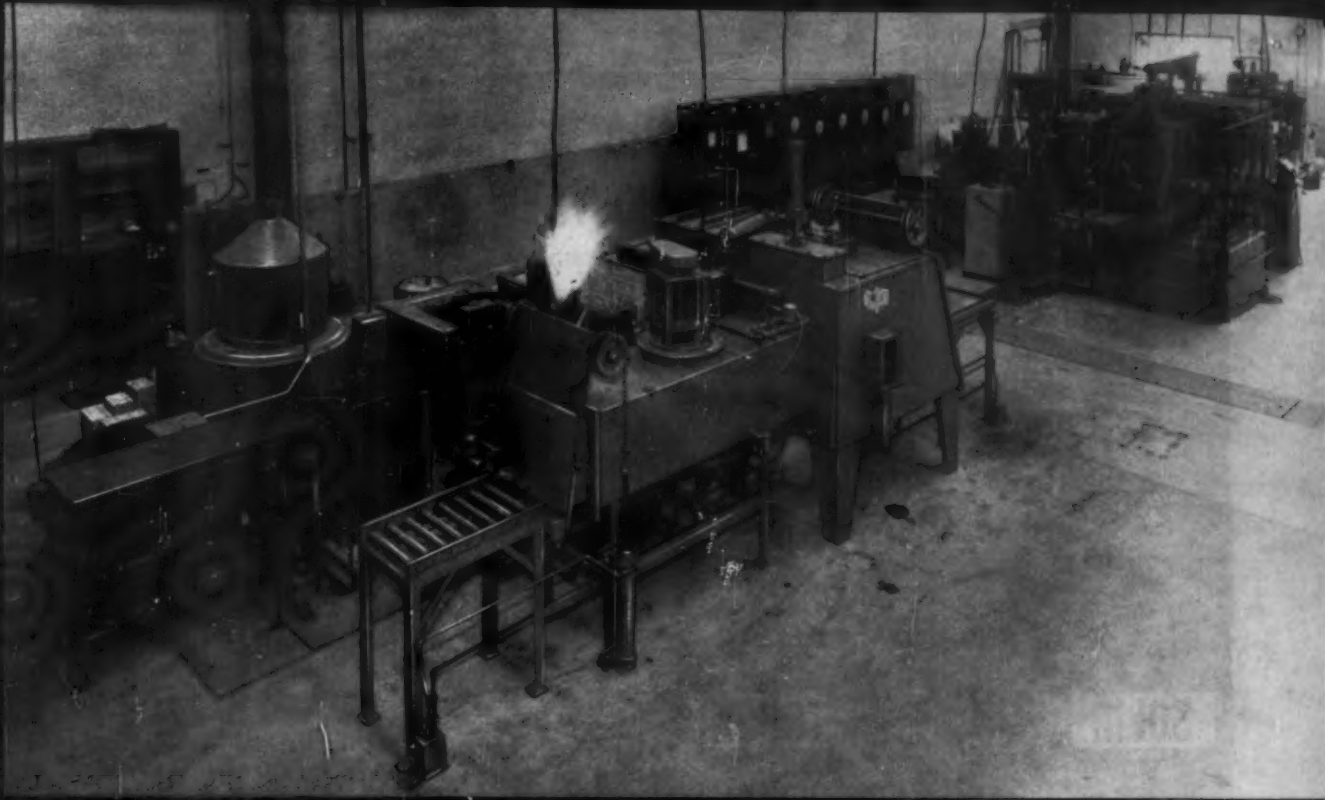
LINDBERG **heat for industry**



High Temperature Furnaces: New Graphite Tube Furnace (shown) with temperature range 2600° F. to 5000° F. for research and production in metal and ceramic fields.

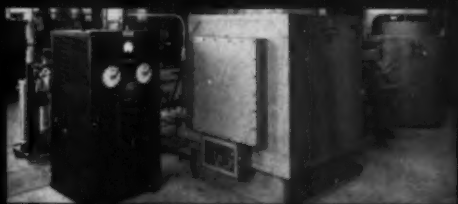


Induction Heating Units: New Lindberg Floating Zone Scanner for precise production of hyper-pure semi-conductor materials and metals and Induction Heating Unit (shown).



General view of complete Heat Treating Department at new plant of Lear, Inc., Grand Rapids, Michigan. All equipment including furnaces, Hyen atmosphere generator, control panels, oil quench is by Lindberg.

Electric atmosphere brazing and annealing furnace. Hand pusher type . . . 2100° F. maximum temperature.



Electric pit furnace for treatment of high temperature alloys in dry hydrogen atmosphere. Tap transformer also shown.

The retort for high temperature pit furnace for treatment of alloys at 2200° F. (left). Production tempering furnace, 22" x 26" work space, shown at right.

Atmosphere tempering furnace, 16" x 24" work space, for both gaseous nitriding and steam treating. One retort in foreground.

LINDBERG Equips Complete Heat Treating Department at Lear, Inc.

The heat treating requirements for the new Grand Rapids plant of Lear, Inc., were put into Lindberg's hands. We supplied them in the way the photographs show. Our engineers cooperated fully with Lear in the selection of the proper Lindberg equipment and the layout of the complete heat treating department. This installation illustrates one of the big advantages of consulting with Lindberg. Our years of experience in all phases of the application of heat to industry, our complete line of all types of industrial heating equipment offer the best assurance that you can coordinate all your needs in one reliable, experienced source. Consult your local Lindberg Field Representative (see classified phone book) or write us direct.

LINDBERG heat for industry

Integral quench furnace with CORRTHERM electric heating elements . . . for carbonitriding and general heat treating.

Welding . . .

(*Continued from p.* 124)

such as Armco iron, which is not susceptible to zinc penetration.

Nickel-Base Alloy Weldments

Julius Heuschkel, Westinghouse Research Laboratories, described studies of the characteristics of arc welds in nickel-base alloys. Little information is available on the strength of these alloys as they are cooled from the solidification temperature. Generally his study indicates that nickel, Monel, and Inconel "X" suffer a loss in ductility as they cool through certain temperature ranges above 1100° F. For example, between 1100 and 1900° F., Monel welds made with covered electrodes had reduction in area values of less than 20%. In the range 1100 to 1700° F., Inconel "X" passed through a sharp decrease in ductility, hitting a minimum of 4% reduction in area at 1400° F. Reduction in area of Inconel welds, however, never went below 40% during cooling.

New Welding Techniques

J. G. Thomas, Aeroprojects, Inc., discussed the progress and characteristics of ultrasonic welding. More equipment is becoming available and the technique has been developed to the point where it is gaining recognition in areas such as electronics and bimetal joining where conventional welding has run into trouble.

Numerous welds were made which demonstrate the versatility of ultrasonic welding for joining thin, dissimilar metals. For example, nickel has been joined to gold, zirconium to copper, silicon to gold, and aluminum to many other metals. Best welds are made at high power with high clamping force between the sheets being joined. The joining mechanism apparently is the interpenetration of the alloys by plastic flow at the interface of the base metals. According to M. W. Brennecke, who reported on work at the Aluminum Co. of America on ultrasonic welding of aluminum, solid-state bonding accounts for about half the width of the joint while the rest of the bond appears to be a mechanical interlocking of the surfaces being welded. Surface preparation before welding seems to be necessary only

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Welding . . .

with the aluminum-magnesium and heat treatable aluminum alloys. One important characteristic of ultrasonic welds: There is no melting at the interface.

Another important technique, electron beam welding, was described by George Burton, Jr., and W. L. Frankhouser, Bettis Atomic Power Div., Westinghouse Electric Corp. Briefly, welding by this method is done by converting the kinetic energy of a high-velocity beam of electrons to thermal energy at the metal surface. The principal characteristic is that the thermal energy is highly concentrated; this results in a narrow weld and heat-affected zone. The process is especially suitable for welding reactive and refractory metals and metals with high thermal conductivity. It has been used successfully for critical welds such as encountered in the fabrication of clad uranium fuel rods where the narrow area of fusion of ultrasonic welding permits sealing the rods without contaminating the cladding metal (Zircaloy-2).

Blisters on Aluminum

Digest of "Cavity Formation During the Heat Treatment of Aluminum Alloys", by I. J. Polmear, *Journal*, Australian Institute of Metals, Vol. 3, November 1958, p. 267-271.

BLISTERING of aluminum alloy parts during heat treatment is a common cause for rejection. For blistering to occur, the material must contain dissolved gas and internal cavities into which the gas may diffuse. Typically, the cavities may be gas porosity, shrinkage, laps or seams. They may also occur due to liquation of low-melting-point constituents if the solidus temperature is exceeded during heat treatment. On occasion they may have formed in material, initially quite sound, during heat treatment in air below the solidus temperature.

Cavities of this last type were produced experimentally in A.A. Alclad 24 S. Test specimens were solution treated for various times in a closely controlled air-circulating furnace just below the solidus temperature, as determined by careful test. Microscopic examination showed


ALCAN

Blisters on Al . . .

cavity formation, frequently adjacent to intermetallic compounds. Some of the compounds had dissolved. Cavity size and number increased with longer heat treatment. Cavity arrangement was markedly similar to that of the compounds prior to heat treatment.

Mechanisms which might account for the initial formation of these cavities are:

1. Submicroscopic pinhole porosity, previously in the material.
2. Formation of molecular hydrogen from hydrogen atoms within the undisturbed aluminum lattice. This could create minute cavities which then act as sinks to collect more hydrogen atoms.
3. Reaction of dissolved hydrogen with some included matter.
4. Coalescence of vacant lattice sites during heat treatment.

A random arrangement of cavities (rather than one related to that of the intermetallic compounds) would have been likely had pinhole porosity, formation of molecular hydrogen or reaction of dissolved hydrogen with included matter been the cause of the cavities. The formation of molecular hydrogen or of a gas by reaction of the dissolved hydrogen with included matter would require deformation of the surrounding material. The force required for this would be very large when the size of the cavity is near zero. Thus, it seems highly unlikely that the cavities were formed in any of these ways.

Coalescence of vacant lattice sites as a source of cavities requires a mechanism by which the vacancies may collect. One suggestion is that the vacancies diffuse to the interface between intermetallic compounds and the matrix. This would explain cavity formation at compounds which are little affected by heat treatment.

When the compound dissolves during heat treatment, the explanation may be more complex. Diffusion in substitutional alloys is now thought to occur through the agency of vacant lattice sites. Studies of diffusion in metallic couples at high temperatures have shown that the interface moves. This is attributed to different diffusion rates of the component atoms. Visible voids form on the side of the interface which has suffered a net loss of atoms. Careful tests have shown that these voids are not connected in any way with gases dissolved in the metals. The vacancies are thought to be generated at grain boundaries, polygon boundaries and edge dislocations. They may coalesce to form small voids. If above critical size, they will continue to grow to visible size by further absorption of vacancies.

If the metallic compound in the aluminum matrix is considered as a diffusion couple, then during solution treatment, the compound diffuses into the matrix and voids may form in or adjacent to the site of the compound. One difficulty with this explanation is that the diffusion couple studies were with cubic metals whereas the readily soluble compounds in this case have tetragonal or orthorhombic lattice structures. However, this does not seem of much consequence.

Blistering may occur in aluminum alloys, initially without defects, through formation of cavities during heat treatment. Vital factors in blister prevention are control of the furnace atmosphere and prevention of diffusion of hydrogen into the alloy.

Though there is no direct evidence as to the origin of the cavities, it is suggested that they may form through the coalescence of vacant

Blisters on Al . . .

lattice sites at the interface of the intermetallic compounds and the matrix. They may also be associated with the generation of vacant lattice sites due to differential diffusion of atoms between the compound and the matrix.

W. E. McKibben

Gold Alloy Plating

Digest of "Recent Developments in Gold Alloy Plating", by Edward A. Parker, *Plating*, Vol. 45, June 1958, p. 631-635.

The present decade has witnessed a major rebirth of technical interest and expanding development in gold alloy plating, largely because of market demands for electronic components. Gold exhibits electrical conductivity properties closely paralleling those of silver, and is largely free of tarnishing problems. It has found widespread use, therefore, in printed circuitry and protective coating applications. But more significantly, gold alloy plating has provided a comparatively simple method for introducing doping agents into transistor materials.

Transistors, which have the ability to rectify a flow of electrical current, achieve this property through the addition of minute quantities of alloy elements from either Group III or Group V of the periodic table. Past practice has been to "dope" the silicon or germanium by making small alloy additions to the melt, then growing single crystals from the alloyed product. The procedure is subject to major difficulties in control and is expensive.

Alloy additions can now be introduced into a Group IV transistor element by diffusion from a gold alloy plated on its surface.

In the process for producing N-type germanium, gold-antimony alloys are plated onto the high-purity germanium wafer, and antimony is diffused into germanium by heating for short periods of time at about 500° C. (930° F.). Experimentally, it has been found that gold alloys with as little as 0.001% antimony will produce the desired result.

P-type transistors are prepared in a similar manner, using gallium, indium or thallium as the doping

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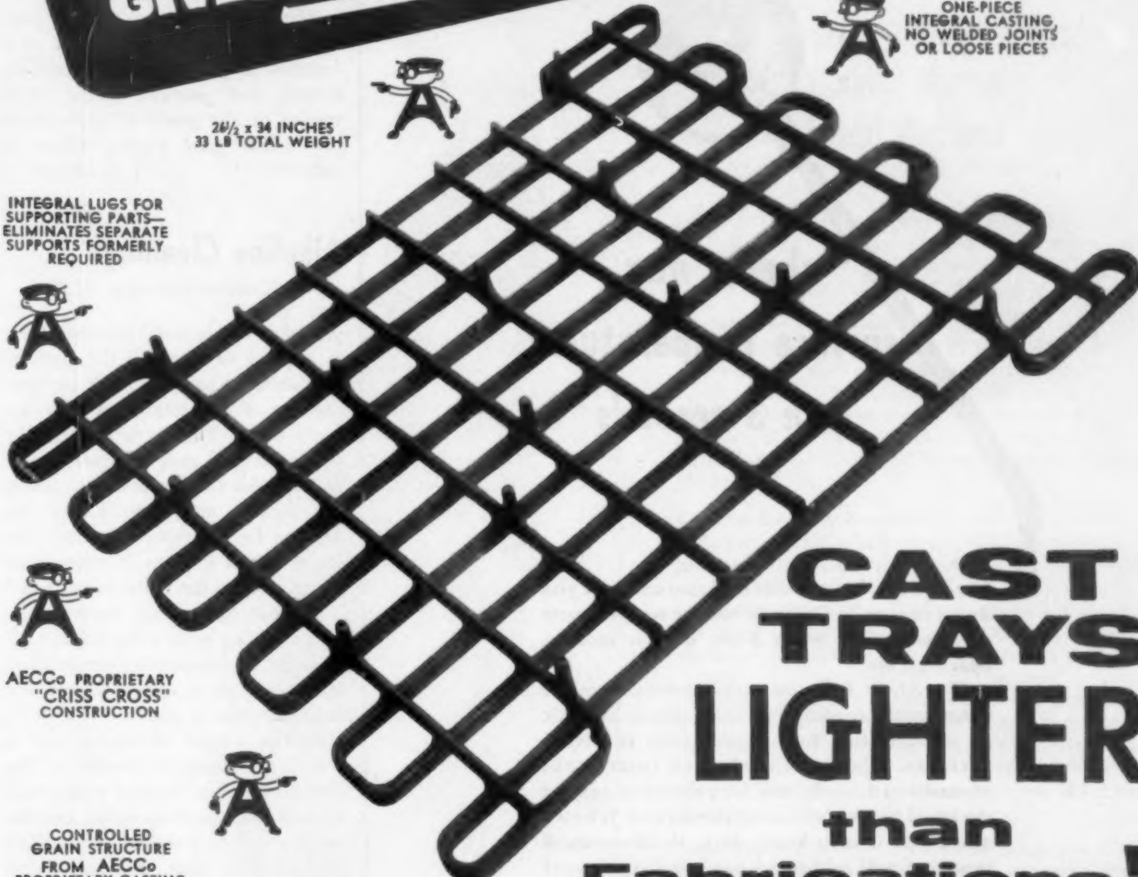

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Gold Alloy Plating . . .

agent. Cyanide baths for the plating operations find wide general use, and may be operated at high yields and efficiencies:

Barrel plating of decorative and jewelry items also is increasing, alloyed gold flash-coatings being used extensively in layers about 0.00001 in. thick.

The paper describes typical plating baths, current efficiencies as a function of gold content of the electrolyte, and provides useful information on the practical applications of various gold plating alloys in industry. J. L. Wyatt

Alkaline Cleaning . . .

(*Continued from p.* 113)

placed in a horizontal position. Heat is applied to "freeze" the pattern. The cleaning index (CI) is the percentage of the total area that appears clean. This is determined by placing a grid over the panel, estimating the CI for several squares at random, and then taking the average for the reported value. The atomizer test is 10 to 30 times more sensitive than the water-break test.*

4. The fluorescent method requires soiling with a fluorescent oil, cleaning, and inspecting under ultraviolet light. It is very slow and less sensitive than 1 and 3.

5. The weight of residual soil is also an evaluation of cleanliness. The cleaned panel is washed with ether, the washings are evaporated, and the residue is then weighed. A modified method is to clean, dry, and weigh the test panel, then soil, clean, dry, and reweigh it. The increase in weight represents the amount of residue soil present.

6. The wiping method is a qualitative test. A panel is coated with pigmented soil, cleaned and then

*H. B. Linford and E. B. Saubestre developed this test in connection with AES Research Project 12. It differs from the spray pattern test of S. Spring in one important respect: The panel must be dried before spraying in the atomizer test. This point might seem unimportant; however, the difference in results is enormous, favoring the drying of the panel before atomizing. Many companies have utilized the atomizer test in evaluating cleaners, setting up standards, and controlling process quality.

Alkaline Cleaning . . .

wiped with a white cloth or paper. The presence of soil on the cloth or paper indicates poor cleaning.

7. In the residual pattern method, cleaned panels are dried at 120° F. for 20 min. After drying, the presence of a stained area indicates residual soil and incomplete cleaning.

8. The radio-isotope tracer technique requires that radioactive atoms be mixed with the soil. Panels are coated uniformly with the soil and their radioactivity is determined. The panels are then subjected to various cleaning cycles and the radioactivity is again determined. Cleaning ability of the various cycles can be evaluated by the amount of radioactivity remaining on the panels. This is the most sensitive test; however, dealing with radioactive materials requires an A.E.C. license, trained personnel, and special types of equipment.

Vanadium Technology...

(*Continued from p.* 118)

These are not significant but only emphasize our lack of full understanding of the metal.

A chapter discusses the methods whereby vanadium can be melted, cast, forged, extruded, rolled and drawn. It is now known that vanadium can be processed in the same way that titanium and zirconium are handled, a possibility that was suggested in this chapter. The success of the extrusion technique, using compressed chips or flakes to avoid the melting step, is noted.

The author's discussion of the oxidation of vanadium emphasizes a basic problem – that continuous exposure to free oxygen, as in air, involves a linear oxidation rate so that above 1250° F. vanadium is incapable of self-protection. This problem has not been solved. However, a detailed account is given of the attempts made to reach a solution.

One of the important applications of vanadium involves alloy additions in low-alloy and high-strength steels and in titanium alloys. Here the author writes about the value of vanadium in general terms. Research workers would probably prefer a fuller presentation but an excellent set of references is included.

An obvious omission in this valuable book is a chapter on application ideas. Although the author did say that vanadium has not been used for any industrial purpose, possibly it would have been advantageous to mention the scale and scope of the experimental applications in which vanadium has or is now being tested; that would have at least given the worker some basis on which to judge possible applications.

Diffusion in Metals

Digest of "Diffusion in Metals", by P. Shewmon, *Industrial and Engineering Chemistry,* Vol. 50, March 1958, p. 492-495.

THIS REVIEW of recent work in diffusion (with an extensive bibliography) emphasizes new de-developments in theory.

The theory of chemical diffusion often assumes equilibrium concentration of vacancies. This is not justified in systems with large concentration gradients where the local sources and sinks fall far short of maintaining equilibrium value of vacancies. The development of porosity in diffusion couples is another indication of deviation from equilibrium concentration.

A theory of self-diffusion in alloys of various solutes in monovalent solvents has been developed around the "electrostatic" interaction between a vacancy and a solute, assuming solute and solvent are the same size. Theory predicts a monotonic decrease in activation energy and diffusion coefficient with increasing solute valence. There is some experimental evidence to support this theory.

The theory of self-diffusion in pure metals has been substantially unchanged for several years. Additional data have been obtained but they add little to a basic understanding of the phenomenon. A study of annealing of the radiation damage produced in germanium by 3-Mev. electrons led to the conclusion that the first 65% of annealing occurs by recombination of interstitials with the vacancies from which they were initially dislodged.

It is generally agreed that diffusion in pure metals (cubic or hexagonal lattices) occurs by a vacancy mechanism. This is not necessarily

Diffusion . . .

true in intermetallic compounds; for example, silver diffuses by an interstitial mechanism in silver bromide. Diffusion of copper in germanium is a complex process since copper can dissolve both interstitially and substitutionally. The apparent diffusion coefficient thus would depend markedly on local perfection of the crystal. Similar effects could appear with slightly soluble elements in metals.

Grain-boundary diffusion has a marked dependence on orientation and structure of the grain boundary. Most data on surface diffusion have been determined by a technique which is applicable only at low temperature. A method, based on the formation of grooves at the intersection of a grain boundary and a metal surface, has been proposed which should make it possible to obtain data on surface diffusion coefficients at temperatures near the melting point. C. O. Smith

Forming PH Steels

Digest of "Fabrication of 17-7 PH and PH 15-7 Mo Stainless Steel by Bend Rolling, Deep Drawing, and Spinning", by C. T. Olofson, Defense Metals Information Center Memorandum 18, Battelle Memorial Institute, Columbus, Ohio.

In the annealed condition, the 17-7 PH and PH 15-7 Mo steels have poorer elongation in tension (30 to 35%) than do Type 301 and 302 stainless steel (50 to 55%). This, plus the more rapid work hardening of the precipitation hardening grades, make them more difficult to form by bend rolling, deep drawing, and spinning. Therefore, forming procedures recommended for Type 301 stainless steel should be used with the following modifications for 17-7 PH or PH 15-7 Mo.

Bend rolling requires 50 to 60% greater power than for carbon steel. Roll wear similar to quarter-hard Type 301 means case hardened rolls are required. Sharper bend contours must be formed using tighter roll settings to compensate for increased spring back.

Deep drawing will require several mild draws with intermediate anneals at 1900° F. If cold work has completely transformed the part,

PH Steels . . .

aging at 950 to 1050° F. will suffice for hardening. Otherwise, anneal at 1750° F., refrigerate to −100° F. and temper at 950 to 1050° F. Dies and punches which have been used include 3% C, 1% Cr, 1% Mo, 12% V at Rockwell C-64.0 to 66.0, and high-carbon high-chromium die steel at Rockwell C-60.0 to 62.0. Cemented carbide dies have been used for long runs and cast iron for short runs. Blank edges must be deburred and free from cracks. Blanks should be annealed in air at 1900° F. and air cooled. Cracked ammonia or endothermic atmosphere may cause poor heat treating response due to carbon or nickel pickup. Drawing speeds of 10 to 20 ft. per min. are recommended. Heavy bodied lubricants such as chlorinated or sulphurized fatty or mineral oils are required for heavy pressure work. Lighter oils or soap solutions can be used for light pressures; they are applied by swabbing, dipping, or spraying.

Spinning requirements include capacity to maintain speed under the heavier tool pressures, freedom from vibration, a true running spindle, and adequate clamping pressure. Mandrels should be of steel or steel reinforced wood. Roller-type spinning tools of hardened and polished steel are preferred. If round nose tools are used, they should be of hardened and polished or chromium-plated steel. A.I.S.I. D 2 and A.I.S.I. O 7 steels having been used for long and short runs, respectively. Bronze can be used for light work. Blanks must be flat, truly circular, free of burrs, nicks, and scratches, of uniform thickness, and clean. Spinning speeds one third to one half of those for carbon steel are recommended. Lubricants such as laundry soap, lard oil, paraffin or soap-grease mixtures must be used.

In all of the above operations, blanks and tools must be free of foreign materials, otherwise corrosion resistance of the part is reduced. Lubricants must be completely removed prior to annealing. After annealing, pickling is preferably preceded by salt bath treatment. Pickling baths of 10% nitric, 3% hydrofluoric acid or sulphuric acid solutions are used. Citric-phosphoric acid is a suitable brightener.

W. E. Littman

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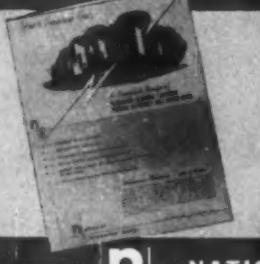

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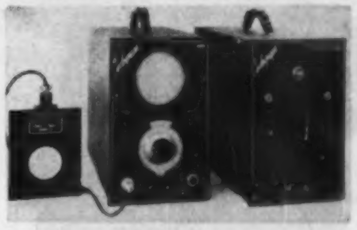

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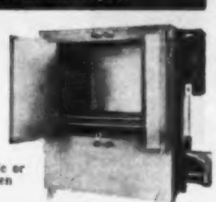

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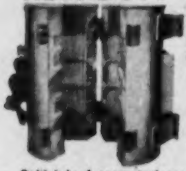

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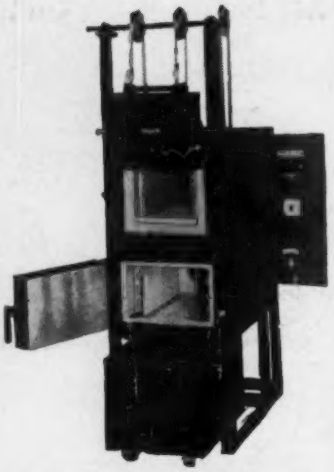

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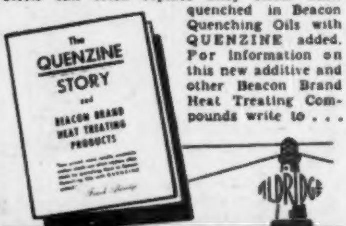

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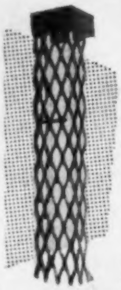

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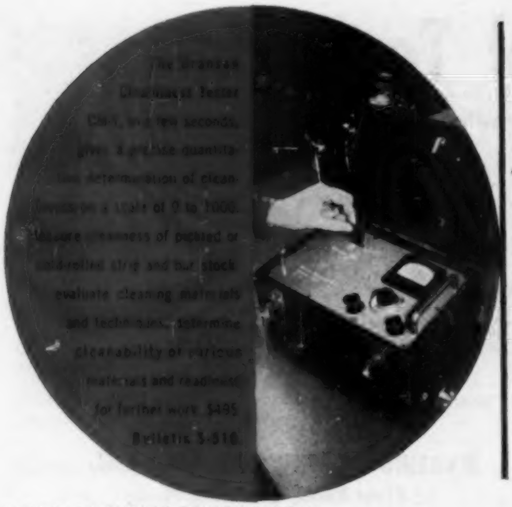

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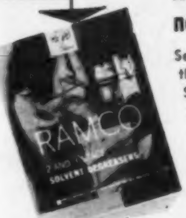

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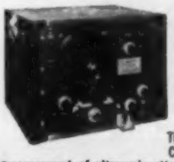

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Porosity in Aluminum Alloy Welds

Digest of "Porosity in Aluminum Alloy Welds", by F. R. Collins, Alcoa Research Laboratories, New Kensington, Pa.

THE OCCURRENCE of porosity in aluminum-magnesium and aluminum-magnesium-silicon alloy welds deposited by the shielded inert-gas consumable electrode process was investigated. The principal factors considered were gas in the plate and wire material, and atmosphere contamination of the shielding gas.

To assess the effects of gas in commercial plate and wire alloys, highly gassed and completely degassed plate and wire alloys were produced in the laboratory by bubbling steam and chlorine, respectively, through the molten metal prior to casting.

A simple test for porosity, which consisted of heating the alloys to a "mushy state" and observing the porosity visually, showed no differences between gassed and degassed plate, whether performed in argon or air, and was therefore rejected.

An overhead welding test by the inert-gas shielded-arc process was then selected, based on the theory that any porosity which developed would be trapped and clearly evident radiographically. All the plate and wire material used was subjected to a rigid chemical and mechanical cleaning process.

Plate alloys were assessed by making one or more fusion passes in the overhead position with an argon-shielded tungsten arc. Weld radiographs were given porosity ratings between 1 (for sound welds) and 5 (for excessively porous welds).

Degassed 5052, 5056 and commercial 3004, 5052, 5056, 5154 and 5356 alloy plate gave porosity ratings below 1½ for up to six passes, whereas 5052 and 5056 alloy plate gave porosity ratings increasing from 3 for one pass to 4 to 5 for six passes. Only the degassed 6061 alloy gave a low porosity rating even for one pass, the commercial and gassed alloys giving a rating of 2½, the porosity rating increasing towards 4 to 5 for six passes in all three instances. The theory that this effect might be due to the high reactivity of Mg_2Si to furnace moisture in the plate was supported by the reduced porosity obtained using freshly dry machined plate.

The effect of electrode wire gas on weld porosity was assessed by the same method as for plate, mainly using 3004 alloy plate as a basis of comparison. For both tungsten arc and consumable electrode processes, some porosity was encountered with gassed electrode wires, but none of the commercial or degassed wires led to any significant weld porosity; 4043 alloy wires were somewhat susceptible, however. Changing the plate alloy did not significantly alter the porosity rating of any of the electrode alloys.

The hydrogen content of commercial plate and wire material was 0.3 cc. per 100 g. in contrast to 1.8 cc. per 100 g. for sound consumable electrode welds. This relatively large amount of hydrogen in the weld appeared to be without any effect upon the mechanical proper-

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Porosity in Welds . . .

ties, possibly because of its finely dispersed condition.

Since clean commercial plate and wire will not be major factors in weld porosity, it was concluded that atmospheric contamination of the gas shield must be important. Experiments showed that a 65% helium, 35% argon shielding gas mixture led to less weld porosity than either pure argon or helium, for normal operating currents and voltages. This was also reflected in the lower hydrogen content of 1.3 ml. per 100 g. for helium-argon arc welds as compared to about 2 ml. per 100 g. for the argon or helium arc welds.

Chlorine additions of 0.05 to 0.20% reduced the porosity of pure helium and pure argon arc welds but not that of helium-argon arc welds. However, chlorine is corrosive to welding equipment, somewhat obnoxious to welders, and can leave a potentially corrosive film on the weld. Chlorinated hydrocarbon gas additions to the shielding gas leave a carbonaceous residue on the weld surface. Up to 10% nitrogen, hydrogen, methane, carbon monoxide and dioxide lead to blackened welds of higher porosity and inclusion content. Oxygen additions up to 1% reduced weld porosity but led to greater oxide formation.

Clean commercial plate and wire alloys are not major factors in weld porosity, which is largely attributable to atmospheric contamination of the gas. A 65% helium, 35% argon mixture is the best shielding gas, but to avoid porosity, use the correct welding conditions and weld on clean plate material.

P. D. Blake

Construction of Atomic Power Facilities

Digest of "Construction of Facilities for Radioactive Work", by C. N. Perleberg, TID-8016, Technical Information Service, Atomic Energy Commission, February 1958, 7 p.

This paper describes certain features of the special laboratories and facilities for nuclear power research at the Knolls Atomic Power Laboratory (KAPL) in New York State. Because the laboratory is situ-

ated in a residential area, rigidly high safety standards were established. For example, to demonstrate the feasibility of operating an atomic power plant in a populated area, it was necessary to design and construct a large container to house the entire reactor and its associated equipment. This shell was built as a pressure vessel to boiler code standards, and was designed to contain the fission products if other safety features failed. The most economical design was a welded steel sphere 225 ft. in diameter – the largest steel sphere in the world. Its self-supporting skin has a thickness of 1 in. and weighs 4000 tons. All welds were inspected by X-ray, and when completed the entire sphere was subjected to a compressed air pressure test of 20 psi., stressing the plates at 15,000 psi.

In the selection of materials for shielding against radiation hazards, concrete is the least expensive. Hot laboratories or cells, some with walls 3 to 5 ft. thick, were required at KAPL to insure maximum protection to personnel. Because of the cost factor, and the desirability of having these walls as thin as possible to save space, various aggregates were used to increase the density of the concrete. In one of these, steel punchings were used as an aggregate. The steel was too heavy and settled to the bottom of the mix. A more successful combination employed magnetic ore with portland cement. This required a stringent control of water and cement, but produced a shield of uniform density weighing 200 to 225 lb. per cu.ft.

To enable laboratory personnel to work safely in these hot cells and to view their work remotely, special windows were developed. These windows, which are best described as the fish-tank type, each have metal on four sides while the viewing sides are composed of two pieces of lead glass 4 in. thick and a space filled with zinc bromide, plus a section of nonbrowning glass 1 in. thick. Each window is designed as a single compact unit and can be removed at any time. It affords as much shielding as an equal thickness of concrete with almost the same clarity of vision as air.

Air supply and exhaust are among the most important considerations in the design and construction of facilities for radioactive work. All "hot" laboratories must be designed to provide necessary ventilation not only to protect the laboratory worker but to control the spread of contamination. At the Knolls laboratory, ventilating systems were designed for maximum flexibility with as much as 30 air changes per hour being provided in some locations. All of the exhausted air is filtered through intricate systems consisting of glass wool filters and chemical warfare service filters to separate dust particles of microscopic size.

Another major problem in the operation of an atomic power plant or laboratory in a populated area is the control and disposal of radioactive wastes. Liquid wastes, for example, are classified into low and high-level materials. The high-level waste is stored until it decays to a point where it can be processed, while the low level waste is processed on a current basis.

Atomic Power . . .

Several years of study on the release of low-level liquid waste to the environment indicated that the major portion of these wastes could be released directly into the Mohawk River without evaporation, but with adequate prior dilution. As a safeguard, all sewer effluent is constantly sampled and then analyzed for total activity discharge. The discharge of low-level waste is such that drinking water tolerance is maintained very near the sewer outfall in the river. Solid wastes which are too hot for shipment require special handling and storage over long periods of time before decay reaches a point where shipment can be made for off-site burial. This necessitated the design and construction of below ground storage facilities located at some distance from other buildings.

The development of atomic power has now reached a point where private industry can participate in its broadening growth. In due time still greater economies will be achieved in the construction of atomic power plants because of the ever growing understanding of this great source of energy.

W. W. Austin

Self-Fluxing Sinter

Digest of "Experience With Self-Fluxing Sinter at the Steel Co. of Canada, Ltd.", by J. T. McMahan. Paper presented at the General Meeting of the American Iron and Steel Institute, May 27, 1959, New York.

This is a discussion of results obtained at the Steel Co. of Canada when a blast furnace was tested with a charge of 100% self-fluxing (calcite) sinter. Daily production increased from 650 tons (on 60% partially fluxed sinter) to 1140 tons of hot metal, according to the report. Also the tendency for the burden to hang was apparently greatly reduced, its descent being smoother and faster. This occurred despite the higher blast temperature, which is normally a big factor in causing hanging.

This gain in production should insure the use of self-fluxing sinter on these furnaces to the very limit of its

Self-Fluxing Sinter . . .

availability. Whenever a gain of over 60% in production and a saving of 30% in coke consumption is obtained by a relatively simple change in the type and amount of sinter used in a blast furnace burden, an important step forward has been made. Of course, much work remains to be done. All of the possible changes which can be made in blast furnace operation must be fully explored to obtain maximum results.

Without doubt, self-fluxing sinter, when used in a furnace all tuned up to operate on it, produces a marked increase in production and a decrease in coke rate. The combination of highest practical blast temperature with the proper sizing of self-fluxing sinter and coke should result in a new day for the blast furnace. Perhaps a relatively small addition of coarse ore and proper steam or moisture additions will be helpful, too.

The paper is easy to understand and indicates clearly the value of any sinter in the burden. It should stimulate the imagination of all blast furnace operators, especially those being hard pressed for more production from the present equipment.

In many instances blast furnace production has been improved by better preparation of the ore. This improvement has exceeded 25% in some instances. When this is added (where practical) to an increase of 50% or more obtained by the free use of self-fluxing sinter, the total improvement in production is great indeed.

High top pressure, and steam and oxygen in the blast, can also contribute to a marked improvement in production. Another possible aid may come through the use of specially designed, external, desiliconizing and desulphurizing equipment. This will permit the operation of the blast furnace with no restrictions because of sulphur or silicon.

While this paper clearly shows what can be done by the use of self-fluxing sinter under special conditions, it also indicates one more way of postponing the financing of the installation of a new blast furnace when increased hot metal or pig iron must be obtained.

H. W. McQuaid

(*More digests on p.* 198)

Tempering Low-Alloy Creep Resistant Steels

Digest of "The Tempering of Low-Alloy Creep Resistant Steels Containing Chromium, Molybdenum and Vanadium", by E. Smith and J. Nutting, *Journal,* Iron and Steel Institute, Vol. 187, December 1957, p. 314-329.

Cast No.	C	Si	Mn	Cr	Mo	V	V/C
1	0.22	0.59	0.59	—	—	0.73	3.32
2	0.23	0.55	0.49	2.96	—	—	—
3	0.21	0.54	0.57	—	0.55	—	—
4	0.21	0.58	0.61	—	0.54	0.72	3.43
5	0.22	0.45	0.49	3.02	0.54	—	—
6	0.22	0.52	0.51	3.08	—	0.73	3.32
7	0.22	0.47	0.52	3.18	0.50	0.75	3.40
8	0.22	0.23	0.46	1.03	0.99	0.20	0.91
9	0.22	0.24	0.46	1.05	0.99	0.39	1.77
10	0.23	0.26	0.49	1.09	0.94	0.59	2.48
11	0.23	0.28	0.52	1.14	0.98	0.73	3.18
12	0.22	0.28	0.54	1.10	0.96	0.87	3.96
13	0.22	0.28	0.53	1.14	0.97	1.11	5.05

Compositions of Various Steels Investigated Are Given in Table at Left

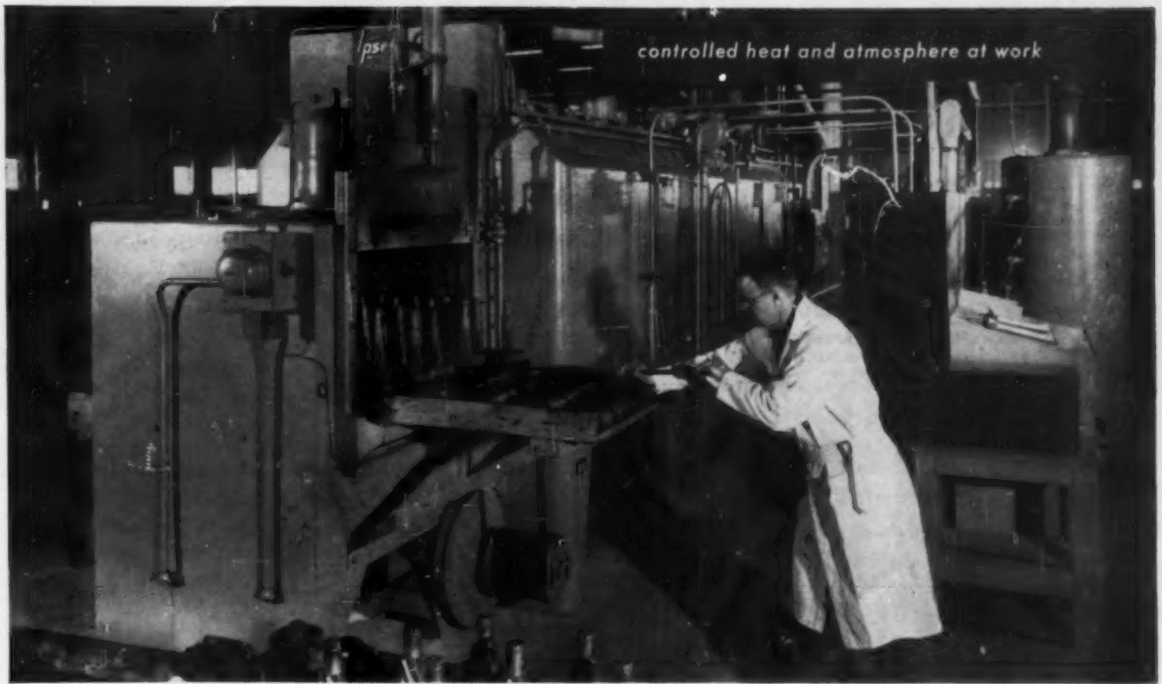
When hardened plain carbon steels are tempered in the temperature range of 750 to 1290° F., the hardness decreases logarithmically with tempering time. Alloy steels containing noncarbide-forming elements also behave in this manner although at a slower rate. However, if the steels contain strong carbide-forming elements such as molybdenum or vanadium, they will react like an age hardening alloy and reach a maximum hardness value. This phenomenon, known as secondary hardening, has been the object of numerous investigations which have revealed that it is associated with the formation of alloy carbides.

The object of this investigation was to determine the microstructural changes occurring during the tempering of 0.2% carbon steels containing up to 3% Cr, 1% V and 1% Mo.

Seven steels were investigated. They were basically 0.2% carbon with varying amounts of vanadium, chromium and molybdenum (see Table) and may be divided into three groups on the basis of the number of alloying elements. Group 1 was composed of three steels, each containing one alloying element; Group 2 was composed of three steels, each containing two alloying elements; and Group 3 was composed of one steel containing three alloying elements.

The steels were made in an induction furnace as 18-lb. melts and cast into 3-in. molds. They were then forged into ¾-in. diameter bars which were cut into ¾-in. thick specimens. The specimens were treated at 1920 or 1975° F. for 1 hr., oil quenched and tempered in a lead bath at temperatures of 750, 930 and 1110° F. and tempered in air at temperatures of 1200, 1250, 1290, and 1380° F.

After tempering specimens were air cooled. The tempering times



Le Tourneau-Westinghouse Company uses this Ipsen "straight-through" controlled atmosphere, semi-automated pusher furnace for hardening final drive gearing and transmission parts used in Le Tourneau-Westinghouse earth moving equipment.

"...we've increased production 25% and reduced costs with our Ipsen pusher heat treating units."

Le Tourneau-Westinghouse Company, Peoria, Illinois

Harold C. Stone is Chief Metallurgist of Le Tourneau-Westinghouse Company, Peoria, Illinois, one of America's leading producers of earth moving equipment. In the following interview, Mr. Stone tells why he is well satisfied with his Ipsen controlled atmosphere pusher heat treating equipment.

Q. What type of work do you run in your Ipsen "straight-through" controlled atmosphere heat treating unit?

A. We use our Ipsen pusher equipment for the controlled atmosphere hardening of final drive gearing, transmission parts, and other parts used in our Le Tourneau-Westinghouse earth moving equipment. Every 15 minutes the furnace receives a 200-lb. charge which remains in the furnace 90 minutes, and in the quench 10 minutes. If necessary, we can increase our charges to 500 lbs. and heat treat 2000 lbs. per hour.

Q. Have you been able to increase production with your Ipsen equipment?

A. We have achieved an approximate 25% increase with our Ipsen unit (as compared with the four salt pots it replaced). Part of this improvement is due to the fact that our work is pushed through the furnace work chambers, and quench, automatically. This, of course, is faster than would be possible if it had to be handled by our operators.

Q. What about your operating or production costs?

A. Fuel costs have definitely been reduced. Gas consumption with our Ipsen unit (including the generator) is less than 1,000 cfh...as compared with a total of 2,000 cfh for the four pot furnaces which turn out less work. Straightening, which was formerly required on about 80% of our parts with long shafts, has been virtually eliminated. And sand blasting is no longer necessary.

Q. What do you think of the automatic quench feature of your Ipsen equipment?

A. We like it because we can set the temperature of the quenching medium and maintain it. As a result, we obtain better quality and less distortion. We save labor by quenching batches instead of individual pieces.

Q. What about maintenance?

A. We haven't had any maintenance to speak of...only routine and preventive maintenance.

Q. Have your men commented on Ipsen equipment?

A. Yes. Our heat treat foreman, Mr. Waldo Dirkes, says it's one of the nicest pieces of equipment we have. He says the pusher furnace is simple to operate and certainly easy to keep clean.

Ask for your copy of a brochure describing the type of Ipsen equipment used by Le Tourneau-Westinghouse.

AUTOMATIC **Ipsen** HEAT TREATING UNITS

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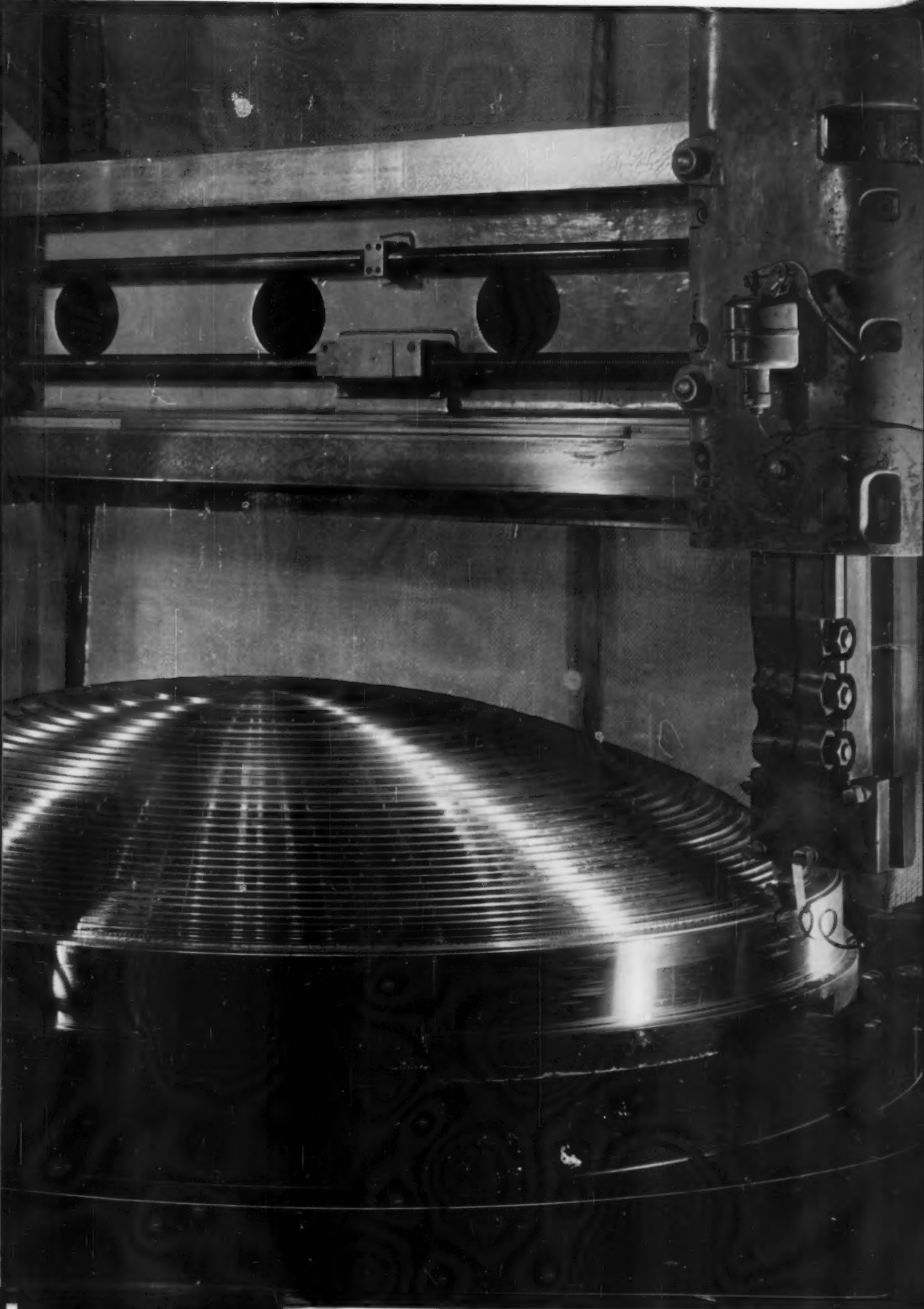
Low-Alloy Steels . . .

were ½, 1, 2, 5, 10, 20, 50 and 100 hr. at each temperature.

The test results of the steels containing a single alloying element revealed that vanadium had the most pronounced effect on secondary hardening. When this steel was tempered at 930° F., the hardness started to increase and was still rising after 100 hr. at temperature. Tempering at 1110° F. produced a maximum hardness after approximately 1 hr. After 10 hr. the hardness began to decrease. Tempering at higher temperatures resulted in a lower maximum hardness after a shorter tempering time. The chromium steel showed no tendency for secondary hardening to occur but did reveal a low rate of softening, particularly at 750 and 930° F. The molybdenum steel containing 0.55% Mo exhibited very little tendency to secondary harden. However, the softening was retarded at 750 and 930° F.

The tests of the Group 2 steels revealed that the behavior of the vanadium-molybdenum steel was very similar to that of the vanadium steel. However, the addition of the molybdenum increased the as-quenched hardness and also the tempered hardness for any given combination of time and temperature. Likewise, the behavior of the chromium-molybdenum steel was similar to the chromium steel with the molybdenum serving to raise the hardness after any given treatment. The chromium-vanadium steel, however, revealed characteristics of both chromium and vanadium steels. Secondary hardening did not occur, but the chromium-vanadium steel did not soften as rapidly as did the chromium steel. The behavior of the steel containing three alloying elements was similar to that of the chromium-vanadium steel. However, the hardness of the triple alloy steel was slightly higher for any given treatment.

Previous investigations had demonstrated that the creep properties of chromium-molybdenum-vanadium steels were dependent upon the vanadium/carbon ratio. Therefore, six more steels with V/C ratios varying from 0.91 to 5.05 were made and tested (see Table, Steels 8 to 13). The best creep properties



Wood proves Stainless Steel is simple to fabricate

General Sales Manager, C. Paul Carlson, points to the Stainless Steel milk cans designed and manufactured by the John Wood Company.

There's probably no one that has more experience and know-how with Stainless Steel fabrication than the John Wood Company. At eight different plants in the U. S. and Canada, the company makes everything from gasoline pumps to milk strainers. At their St. Paul plant they are equipped to produce 50% of the Stainless Steel can requirements for the entire dairy and dispenser industries.

The company worked closely with sanitation experts and health officials to design a Stainless Steel can that meets the strictest regulations for both material and workmanship. And at the same time, they found ways to simplify fabrication and save time and materials. They developed methods of hydraulic forming, welding, grinding and polishing that have paid off in lower costs and a quality product. These Stainless cans have a hard, durable finish that is easy to clean, ready for long, sanitary service. The John Wood Company proved that Stainless Steel isn't difficult to fabricate, it's just different.

If *you* would like to have complete information about working with Stainless Steel, write for a free copy of our *Stainless Steel Fabrication Book.* United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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United States Steel

Low-Alloy Steels . . .

were obtained from steel No. 11 although practically identical results were obtained from steel No. 12. The behavior of steels No. 8, 9 and 10 was similar to that of No. 11; however, the lower V/C ratios resulted in lower hardnesses. Steel No. 13 showed characteristics similar to the other steels when tempered to peak hardness. However, when the tempering conditions exceeded the requirements for maximum secondary hardening, it softened more rapidly than steels No. 11 and 12.

A possible explanation of the results obtained is as follows: Vanadium carbide is nucleated separately within the ferrite grains as small plates, which grow larger with further tempering. Chromium stabilizes ϵ-iron carbide, which then transforms to cementite and finally to Cr_7C_3. The rate of growth of chromium carbide is much greater than that of vanadium carbide. The addition of molybdenum modifies the form of the precipitated cementite, but Mo_2C is not precipitated until high tempering temperatures are attained. In the presence of chromium and vanadium, molybdenum carbide is not readily formed.

During tempering the ferrite matrix recrystallizes, but, if large carbide particles are formed at the ferrite grain boundaries, ferrite grain growth may be hindered.

Bernard Trock

Thermometer for High Temperatures

Digest of "High-Temperature Resistance Thermometry", Summary Technical Report STR 2420, National Bureau of Standards, Washington, D.C.

Development of new high-temperature processes requires accurate temperature determinations and the extension of temperature-measuring techniques. The National Bureau of Standards has developed a platinum resistance thermometer for interpolating between fixed points on the International Temperature Scale (ITS) above 1167° F., the melting point of antimony. In addition to simplifying and smoothing the scale, it is expected that its use at temperatures up to 1945° F.,

. . . designed for industrial applications

The new Honeywell T654A is a rugged, dependable, yet modestly priced indicating temperature controller designed specifically for industrial use. It includes these features:

- Indicating and control setting dials clearly visible.
- Set point changed by turning knob on front of case.
- Even graduations in a variety of ranges.
- Sensitive, liquid-filled thermal system.
- Complete case and tubing compensation for ambient temperature.
- Armored capillary tubing.
- MICRO SWITCH* SPDT narrow differential snap switch.

Get complete details from your nearby Honeywell field engineer.

Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

*Trademark

Honeywell

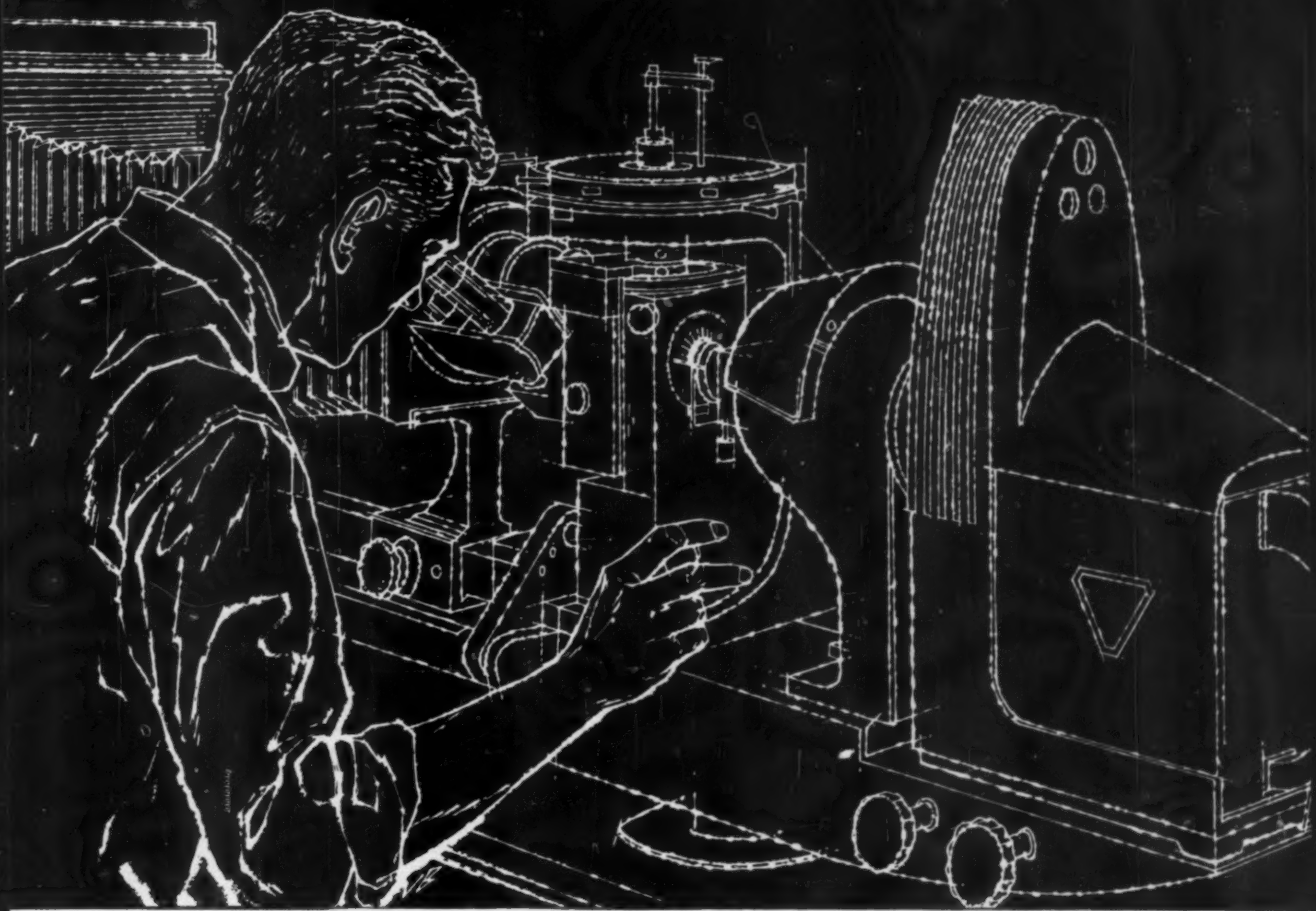
H HONEYWELL *First in Control*

the gold point, will provide greater precision and reproducibility.

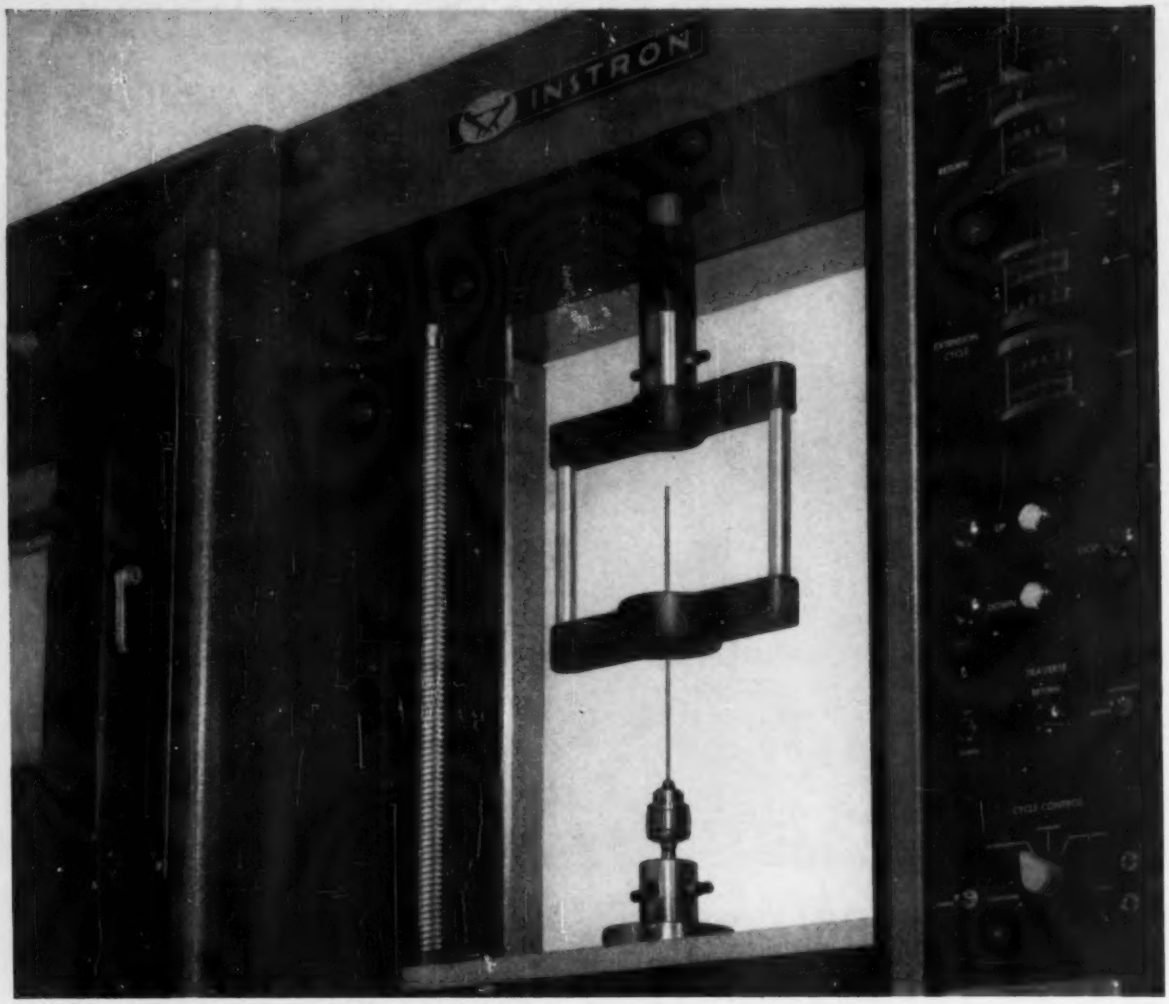
Platinum resistance thermometers have been designed which have drifts of less than 0.001° per hr. at 1830° F. To achieve this stability, highest purity platinum wire had to be used for the temperature-sensing resistor, and the resistor had to be supported in a strain-free manner; materials without silica were necessary for supports and protection.

In one successful thermometer, four equally spaced synthetic sapphire disks (about ¼ in. diameter) support the resistor wire. Eight relatively heavy lengths of platinum wire, about 1½ in. long, are threaded through holes in the disks and welded together at the ends to form a single continuous electrical conductor; its resistance at 32° F. is 0.25 ohm.

Four leads of platinum wire, supported by synthetic sapphire plates, are joined to the resistor and the entire thermometer assembly is encased in a protecting tube of high-purity fused alumina. C.R.W.



The small unit rotary annealing method assures precision temperature control and develops optimum hardness and microstructure for strip steels.



Specially fitted Instron acts as wire-drawing machine to evaluate lubrication performance

HOW THE INSTRON COMES THROUGH IN THE STRETCH... as a metal forming machine

The versatile Instron Testing Instrument was recently asked for a new answer to an old problem in the field of metal forming — finding a better, more precise way of evaluating lubricants without recourse to expensive, time-consuming "cut-and-try" production runs.

The solution: an Instron tester was specially fitted with wire-forming dies — thus transforming it into an actual metal forming machine capable of making highly accurate measurments of the performance of each lubricant tested in terms of finish and foot-pounds of work required *under production conditions*.

This is just one more example of what we mean when we say "you can do more with an Instron".

(If you're interested in the particular test mentioned above, just ask for Bulletin *X-1*. If you have other problems in mind, chances are we have something that will interest you. Among the articles on advanced testing techniques that are yours for the asking: testing tungsten at high temperature . . . stress-strain properties of textile fibres . . . physical properties of plastics and elastomers . . . characterization of pressure-sensitive adhesives. Let us know your field of interest.)

INSTRON®

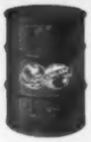
ENGINEERING CORPORATION

2507 WASHINGTON STREET, CANTON, MASS.

EUROPEAN OFFICE: SEEFELDSTRASSE 45, ZURICH, SWITZERLAND

YOU CAN DO MORE WITH AN INSTRON

The unusual versatility of this fine testing instrument is greatly extended by Instron's complete range of special accessories which can be added as you need them. They include: digital equipment • conditioning cabinets • XY recorder for extensometers • quick-change crosshead speed selector • capillary rheometer • high temperature equipment.



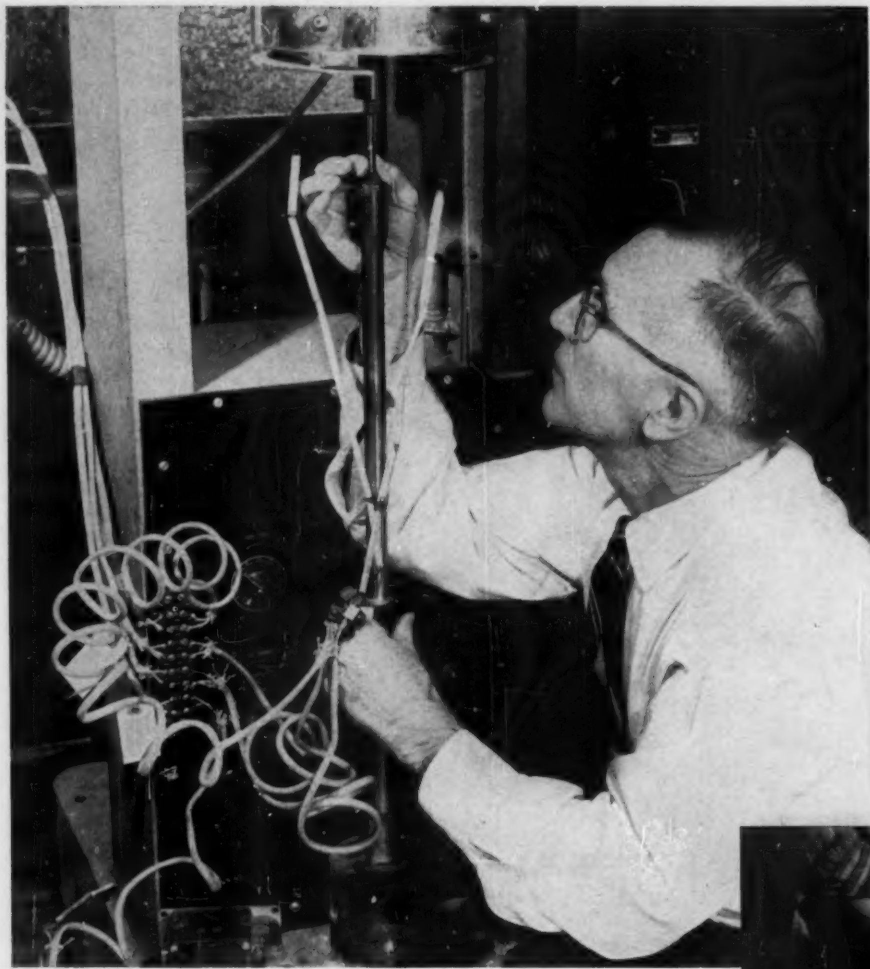
...where a little heat generates a lot of light! We're in Cambridge, Ohio, at VCA's modern Research Center and Pilot Plant. Here is where answers are found to all manner of questions about ferroalloys and their use.

Although the Pilot Plant is only one part of VCA's Research Center, its function is most important to our customers. For here melting equipment of all kinds helps develop new VCA processes and products, in addition to solving direct customer problems. Each year "hundreds of heats" are melted without thought of selling price or profit.

This special service is just another reason why, "There's more in the Vancoram Green Drum than you can ever see!" Let these and other special services go to work for you. Call or write your nearest VCA office. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y. • Chicago Cleveland • Detroit • Pittsburgh

VANADIUM
CORPORATION OF AMERICA
Producers of alloys, metals and chemicals

VANCORAM



Physical tests at Standard include those for special properties of steel alloys under extreme variations in temperature. Here, the strength and ductility of steel are being checked for resistance to stress under severe conditions of elevated temperatures over a prolonged period of time.

Charpy impact and transition temperature determinations have recently assumed importance in many applications. Here a steel sample is immersed in liquid nitrogen to determine its susceptibility to fracture at temperatures as low as —300°F.

Quality control—a vital activity at Standard Steel Works

Every conceivable shop and laboratory test required for modern quality control can be performed by Standard's staff of metallurgical technicians. Testing of incoming raw materials; physical property tests of steel and other alloys at temperatures from several hundred degrees below zero up to red heat; gas analysis, ultrasonic, X ray, magnetic particle, fluorescent penetrant and microscopic examination of finished products are routine checks which assure that the finished, delivered product will meet the most rigid specifications. Write Department 3-L for full details.

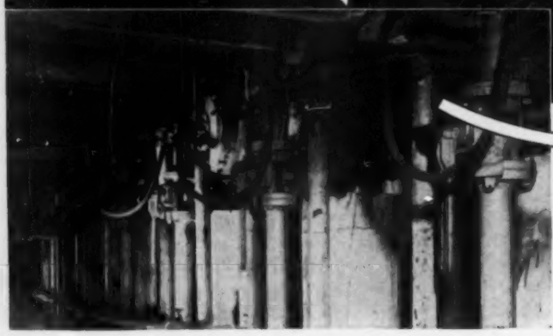
Standard Steel Works Division

BALDWIN · LIMA · HAMILTON

BURNHAM, PENNSYLVANIA

Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes

ARMCO uses North American
Refractory-Lined Dual-Fuel Burners



Four new Salem-Brosius slab heaters in Armco Steel Corporation's Middletown Works Hot Strip Mill are fired with North American Series 6819 Burners with internal mixing oil atomizers and Sensitrol Valves. Air is preheated to 700 F. Fuel is natural gas or #6 oil.

The top bank of each furnace has eight 10" burners and two 8" burners firing in the direction of work travel; bottom bank has five 10" burners and two 8" burners firing in the opposite direction. Each 10" burner releases 5,200,000 Btu/hr with 700 F air at 2" wc; each 8" burner releases 3,600,000 Btu/hr.

Furnaces are 27' wide x 34' long inside, and are designed for 125 tons of hot slabs per hour.

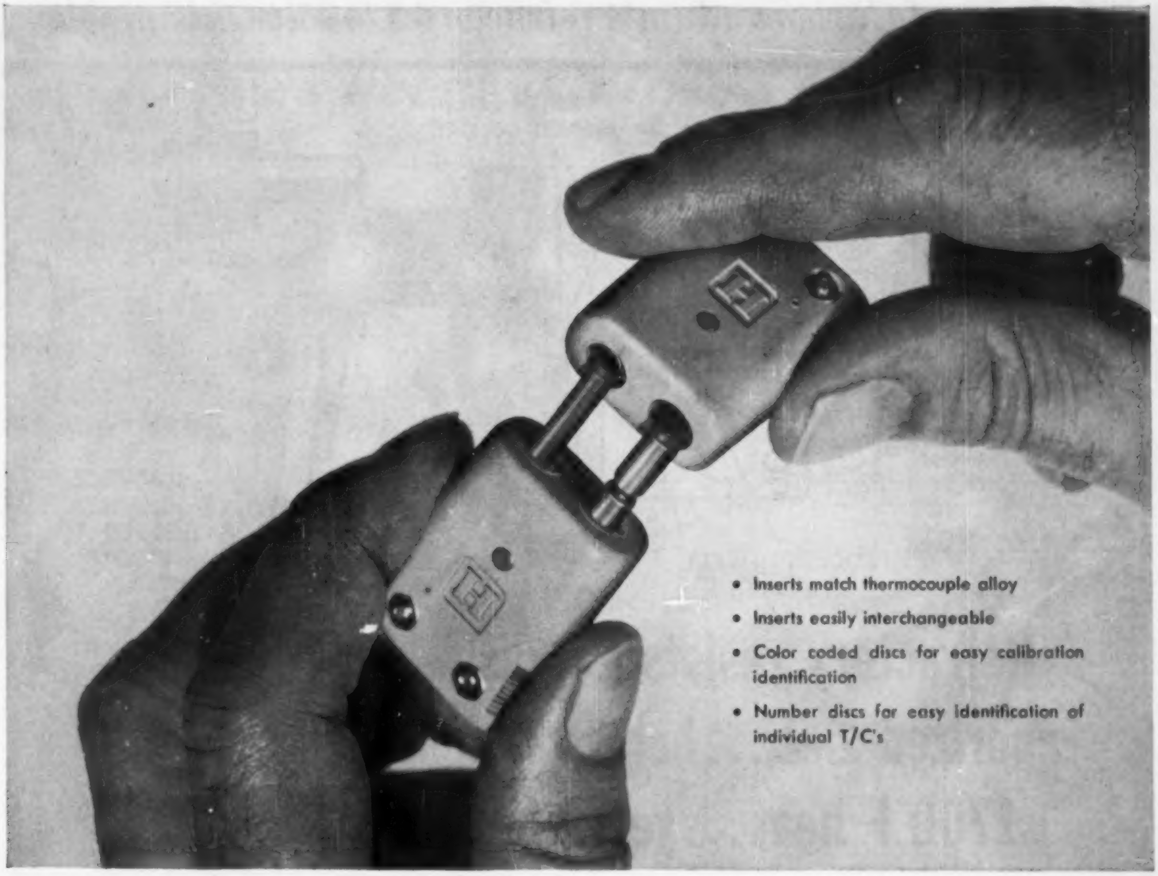
Here's Why You Should Too:

1. **Low maintenance**—quality alloy and refractory materials—metal parts not exposed to furnace radiation—designed for 1200 F preheated air.
2. **Easy accessibility**—quick disconnect atomizer—all parts removable from back.
3. **Retractable oil atomizer**—can be pulled back quickly and easily for gas firing.
4. **Gas and air openings proportional** for all sizes; so a variety of burner sizes can be used on the same manifold.
5. **Long or short flame** models available.
6. **Internal or external mixing atomizers** available.
7. **Low first cost**—plus North American's reputation for good service—in engineering and on the job site.

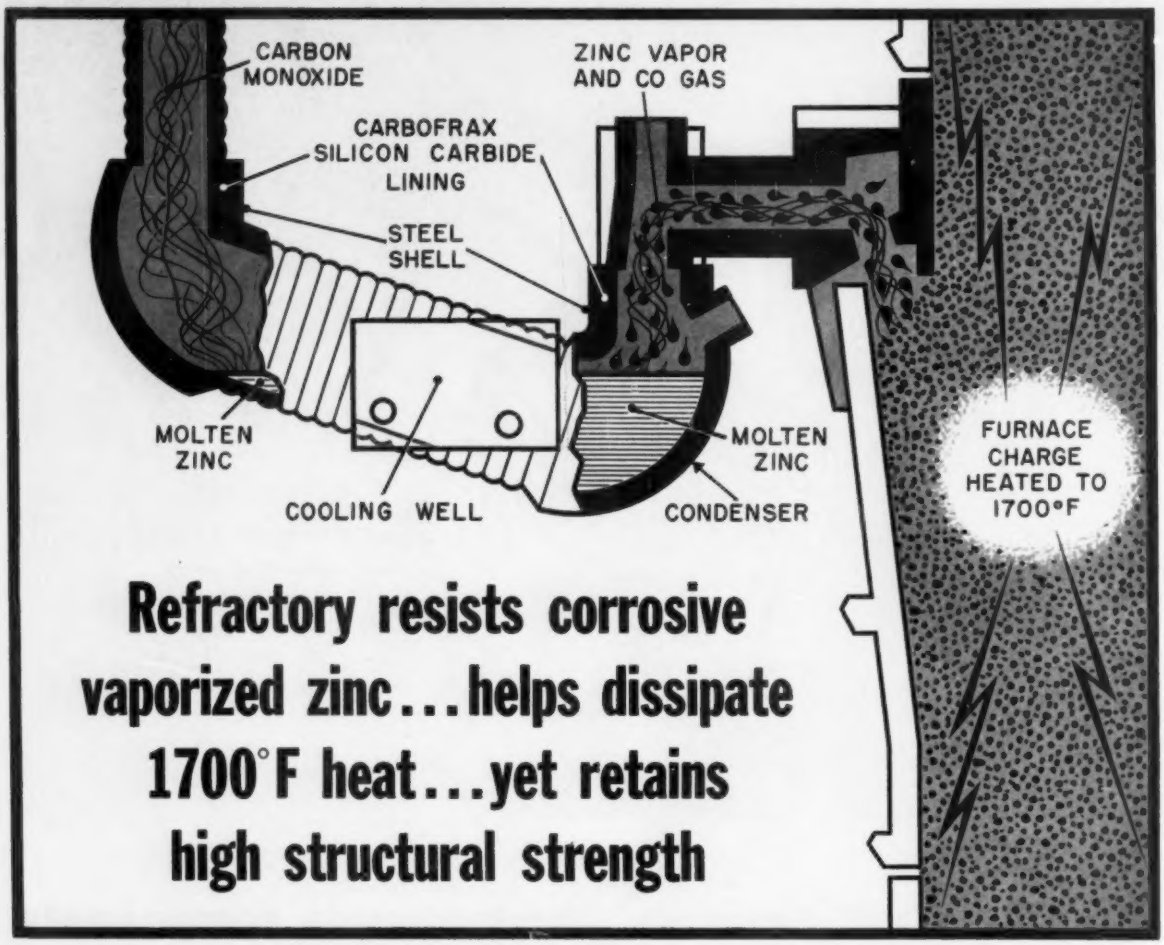
NORTH AMERICAN for COMBUSTION and Hydraulic Controls

Call your nearby North American engineer or write for DF 6819

The North American Mfg. Co.
Cleveland 5, Ohio


• Inserts match thermocouple alloy
• Inserts easily interchangeable
• Color coded discs for easy calibration identification
• Number discs for easy identification of individual T/C's

It took one of Carborundum's refractories to solve this problem:



Refractory resists corrosive vaporized zinc...helps dissipate 1700°F heat...yet retains high structural strength

A major producer of high purity zinc reduces zinc ore by an electro-thermic process. Sintered ore and coke, heated in a resistance furnace to approximately 1700° F, produce vaporized zinc and carbon monoxide. Collected in a vapor ring, these gases pass into a condenser containing a large amount of molten zinc. Here, the vaporized metal is condensed and the carbon monoxide exhausted.

Refractory linings for the vapor ring, condenser and tapping well must not only possess high hot strength, but also withstand the intensely corrosive action of the molten and vaporized metal. They must also be impermeable to gas seepage. In addition, high thermal conductivity is required, since huge amounts of heat must be dissipated to obtain rapid cooling of the zinc vapor.

This tough combination of requirements is met by one of Carborundum's refractories—CARBOFRAX® silicone carbide. It has exceptional load bearing strength at high temperatures (300 psi at 2750° F without crushing) and almost complete impermeability to gases. CARBOFRAX refractories are also chemically inert—resist most acids, acid sludges and fluxes, and molten and vaporized zinc. Moreover, thermal conductivity is high—11 times greater than fireclay.

Properties such as these may be the answer to a problem in your plant. If even the best of standard materials fail to give the performance you need, consider Carborundum's refractories. There is a wide range of products to meet the requirements of almost every type of application.

Write today for your free copy of "Super Refractories by Carborundum." The address: Dept. M-129, Refractories Div., Perth Amboy, New Jersey.

CARBORUNDUM

Registered Trade Mark

News about COATINGS FOR METALS

from Metal & Thermit Corporation

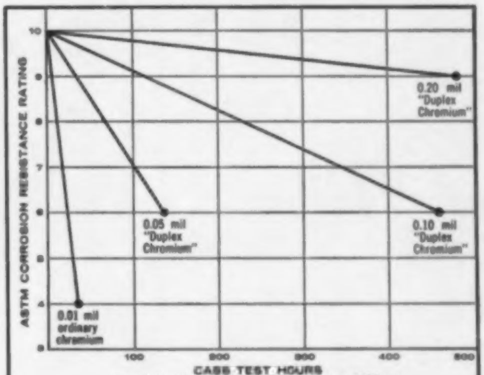
How to get the optimum protection of bright chromium plating

There are three requisites to increasing corrosion protection from chromium plating. (1) The deposit must be sufficiently thick. (2) There should be a crack-free chromium base topped by a special, finely cracked chromium deposit. (3) The plate should be more uniformly distributed over the part, so that recessed areas, too, are assured at least 0.03 mils minimum chromium thickness.

All of these requirements are easily met through UNICHROME SRHS® CHROMIUM plating processes. Work done for the automotive industry, long plagued by corrosion of brightwork in outdoors exposure, provides a good case in point.

AN ANSWER TO OUTDOOR CORROSION

Note the results in the chart at right. In all cases, the thickness of undercoats was kept constant. Only the chromium plate was varied... from ordinary to "Duplex", and progressively thicker. M&T "Duplex Chromium" calls for first using Unichrome Crack-Free Chromium and its ability to throw into recesses and give a more uniform and fracture-free plate. This is followed by another deposit of Unichrome SRHS Chromium, with its *controlled* cracking. With increasing thickness, the protection increased tremendously. Durability as determined by rigorous, accelerated corrosion testing techniques was multiplied as much as ***20 times***.



Corrosion resistance of zinc base die casting in CASS test.

Zinc die cast specimens, all plated with 0.75 mil copper and 0.75 mil nickel prior to chromium lasted as shown above in the severe CASS test (Copper accelerated acetic acid salt spray). Ordinary chromium fared poorly. Optimum protection was approached by using Crack-Free Chromium and increasing the deposit thickness.

Despite severe service conditions, automotive brightwork can stay bright now, due to the additional corrosion protection that M&T "Duplex Chromium" provides.

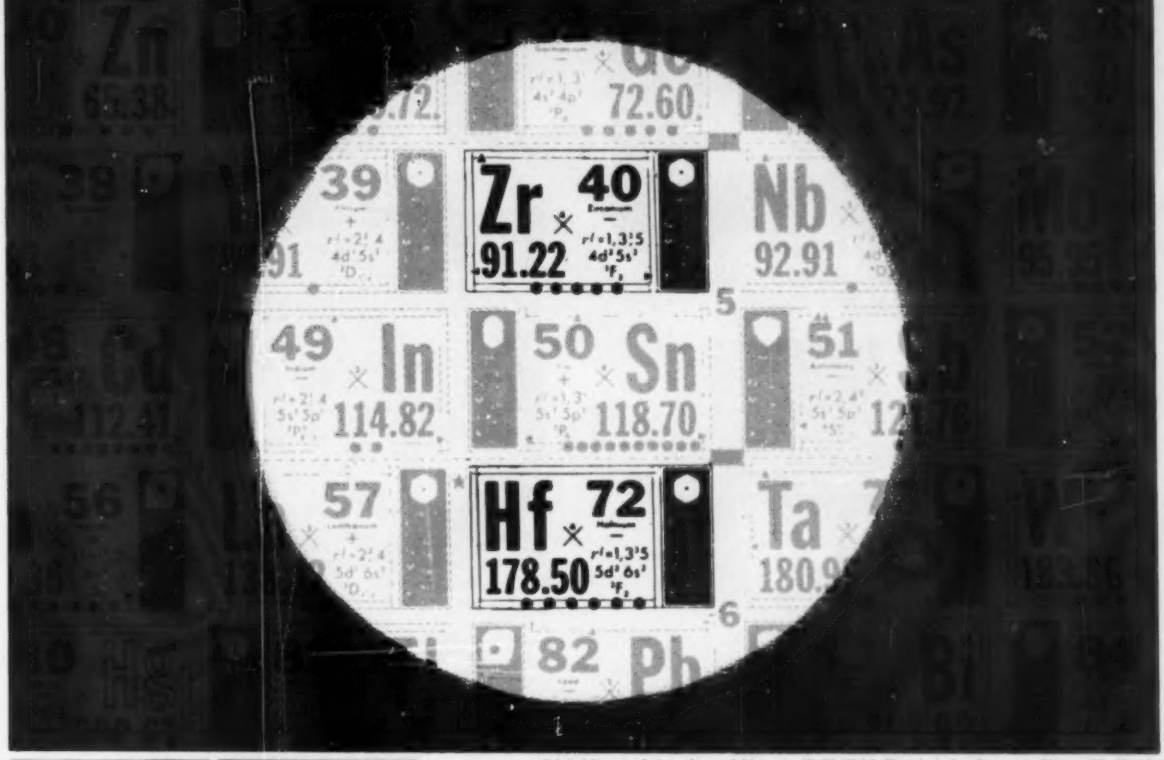
WIDELY USEFUL FINISH

While the above case concerns itself specifically with an automotive problem, it indicates what thicker chromium in general, and crack-free chromium in particular can do for other design problems involving corrosion and wear. This plate blocks infiltration of corrosives to underlying metal.

Technical Papers giving full details on the advantages of thicker chromium deposits are available for the asking. Write METAL & THERMIT CORPORATION, Rahway, New Jersey.

METAL & THERMIT CORPORATION

Accent on Precision Tolerances
Of General Plate Zircaloy and Hafnium



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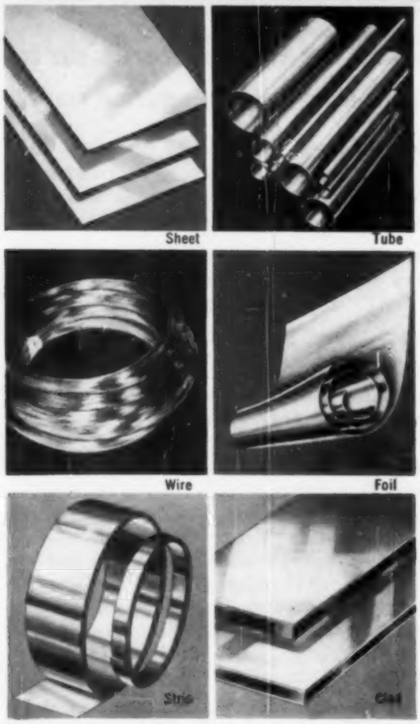

Sheet · Tube · Wire · Foil · Strip · Clad

Yes, accent on extremely close tolerances, but General Plate zircaloy and hafnium mill products are more than precision metals . . . they are also more efficient and less expensive products. The reason . . . Metals & Controls' work with new and unusual metals has led to the development of improved processing techniques for obtaining precise, efficient reactor metal forms.

Precision tolerances are a specialty at M & C. Tolerances on camber, cross bow, and longitudinal bow are held according to specifications. Precision measuring devices (electrical cross bow tester, granite surface plate, ultrasonic and radiographic testers) assure the closest control of quality.

Zircaloy II and III sheet, strip, foil, wire, rod, and seamless tubing are fabricated in solid, clad or alloy form. Patented solid-phase bonding techniques are used to clad invar and stainless steel with zircaloy.

Hafnium is supplied in sheet, strip and foil form, solid or as an alloy. The complete fabrication process from crystal bar to finished plate is performed in clean areas where the material is free from contamination from fissionable materials.

For more information or technical assistance on mill products of solid reactor metals, or on clad metal combinations for special applications, request our new bulletin, "General Plate Reactor Metals," or write directly to Product Manager, Reactor Metals at:

METALS & CONTROLS

312 FOREST STREET, ATTLEBORO, MASS., U. S. A.

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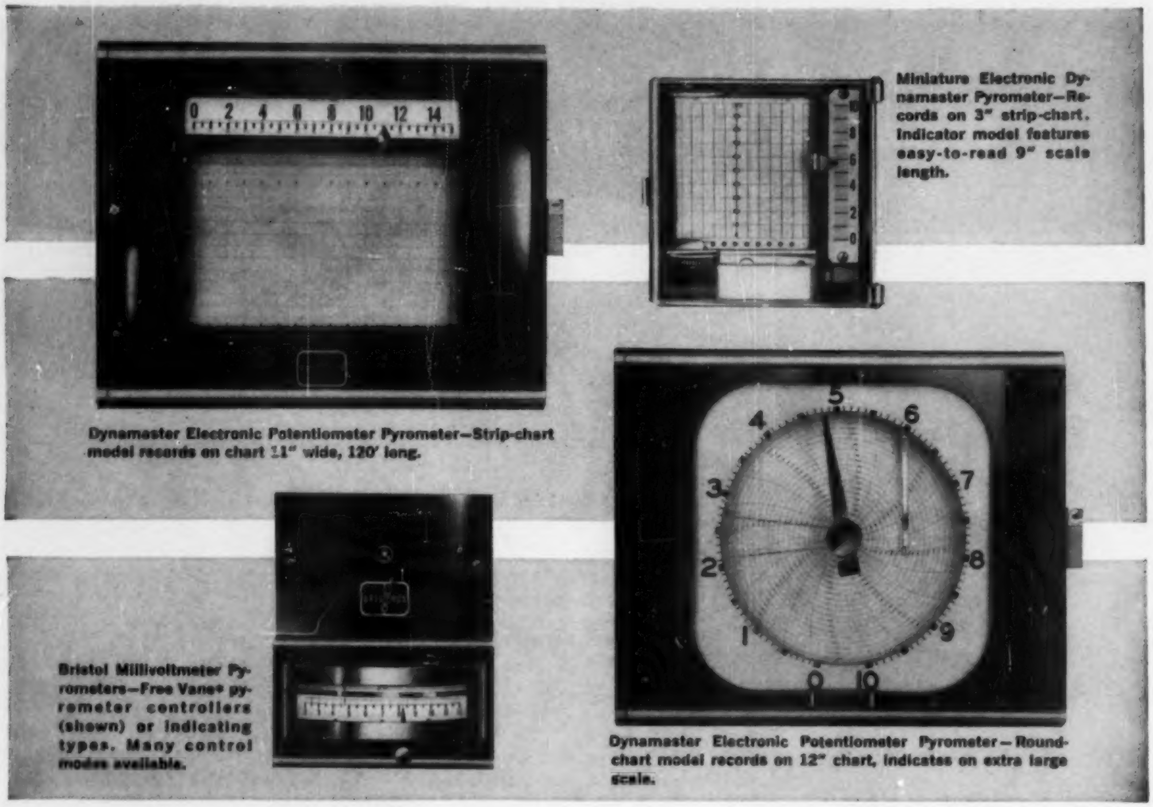
GENERAL PLATE PRODUCTS: Clad Metals • Electrical Contacts • Truflex® Thermostat Metal • Platinum Metals • Reactor Metals • Radio Tube & Transistor Metals



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.

Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.

Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

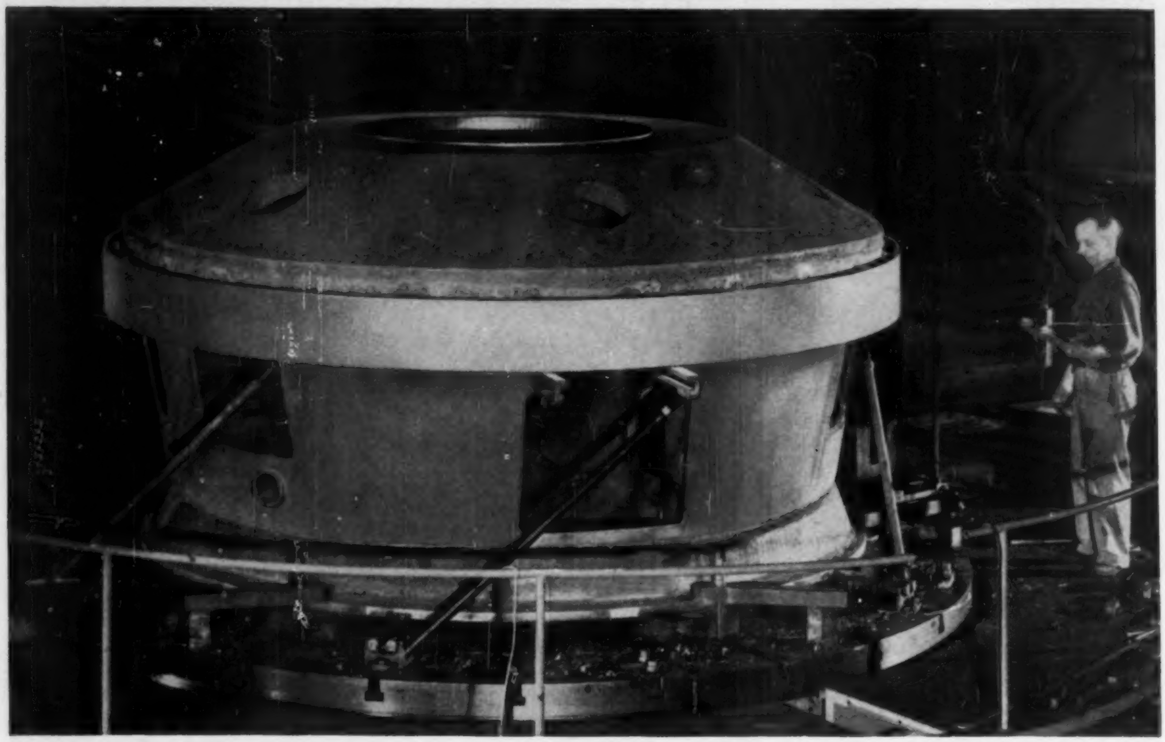
Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5⅛" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U.S. Pat. Off. 9.9

BRISTOL... for improved production through measurement and control

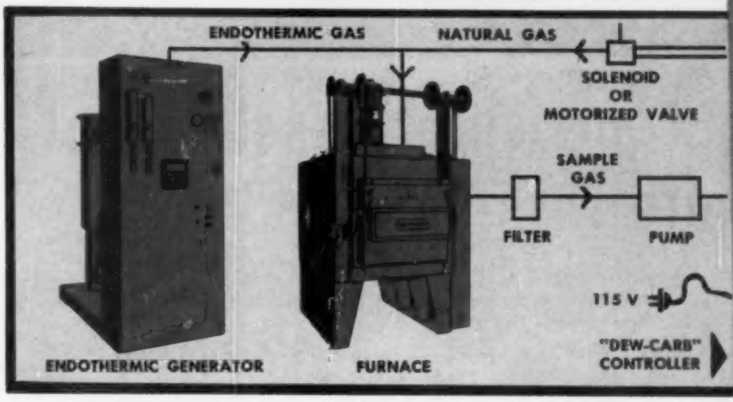
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

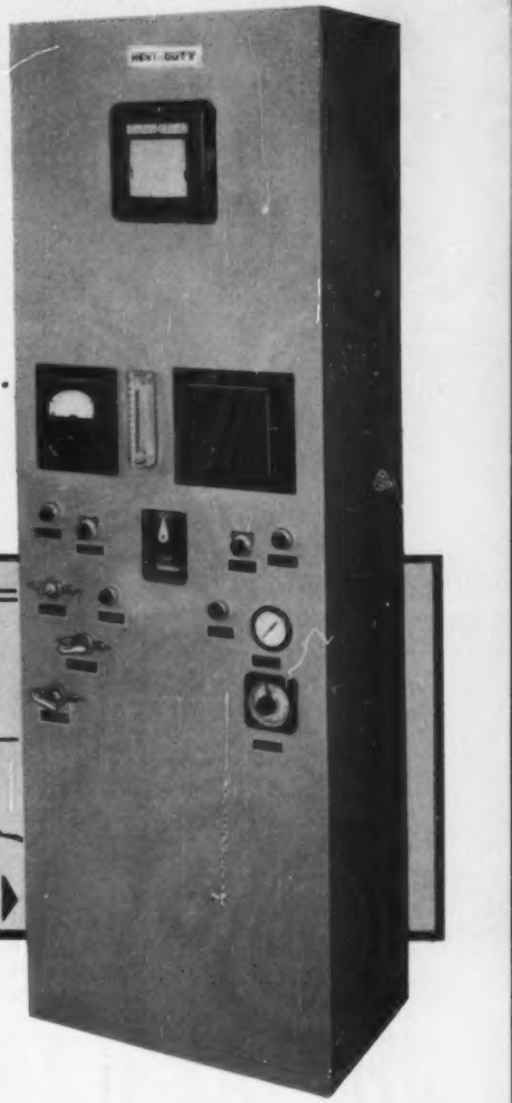


NEW . . . instrument for controlling carbon without cooling . . . from

HEVI-DUTY

"Dew-Carb" Controller measures dew point... controls atmosphere carbon





Provides instantaneous response to sudden change of dew point of furnace atmosphere.

Assures precise measurement of moisture in furnace atmosphere — minus 5° to plus 60° F. dew point.

Does not require cooling of gas sample.

Hevi-Duty's new "Dew-Carb" Controller operates on a wet-dry bulb principle, measuring *precisely* the dew point in controlled atmosphere for furnace processing — bright hardening, carbon restoration, carburizing . . . controlling of surface carbon concentration and depth characteristics. No chemicals, such as lithium chloride, are required in this system.

Hevi-Duty's "Dew-Carb" Controller can be utilized in three types of furnace applications:

1. To *monitor* endothermic generator gas, or the gas within the furnace.

2. To *measure* dew point and instantaneously regulate the carbon in endothermic atmosphere. Instrument can be adapted to either generator or furnace . . . can be used with one generator supplying endothermic gas to several furnaces . . . gas for each furnace can be separately measured.

3. For batch type, enclosed quench furnace applications, such as the Hevi-Duty "Clean-Line" furnace, an automatic system restores atmosphere equilibrium immediately after loading of the furnace, and restarts automatically when load reaches proper temperature.

For more information on the new "Dew-Carb" Controller, write, or call Hevi-Duty today.

HEVI-DUTY

A DIVISION OF BPC BASIC PRODUCTS CORPORATION

HEVI-DUTY ELECTRIC COMPANY, MILWAUKEE 1, WISCONSIN

Industrial Furnaces and Ovens, Electric and Fuel • Laboratory Furnaces • Dry Type Transformers • Constant Current Regulators

The use of 299 tons of USS "T-1" Steel in these two Hortonspheres saved 216 tons of carbon steel and 42% in shipping costs. Designed and erected by Chicago Bridge & Iron Company for storing propane gas in Venezuela. These tanks were designed to the old code limits, but under the new code limits they could have been made up to 9.5% lighter.

Now you can cut pressure vessel weight even more with USS "T-1" Steel

Revisions in case 1204-4 of the ASME Code for boilers and pressure vessels increase maximum allowable stress value to 28,750 psi for "T-1" Steel. This permits further reductions in weight up to 9.5%.

The new figure of 28,750 psi represents an increase of 9.5% over the previous maximum allowable stress value of 26,250 psi which applied to USS "T-1" Constructional Alloy Steel used in pressure vessels. This means that USS "T-1" Steel can be used to reduce weight even more than it did before in stationary vessels or truck tanks.

The steel frequently used in welded, unfired pressure vessels is ASTM A-285-Grade C. This steel can be used with a maximum allowable design stress of 13,750 psi. From this, you can see that the allowable stress for "T-1" Steel is 2.1 times greater. To put it another way, plates of "T-1" Steel in a pressure vessel need be only half the thickness of A-285-C plates to withstand the same stress.

15% overall savings possible with "T-1" Steel

USS "T-1" Steel permits a 50% reduction in the amount of steel used in the vessel; this results in large savings in the cost of structural supports and foundations, welding, freight, handling costs and the elimination of stress relieving costs.

In a recent design, pressure vessels designed of both A-285-C steel and "T-1" revealed the following cost analysis:

	Use of "T-1"
Weight of steel	saved 50%
Cost of steel	only 20% more
Fabrication cost	saved 40%
Freight	saved 50%
Amount welding wire	saved 60%
Total savings	**15% cheaper overall**

These savings, plus USS "T-1" Steel's unique combination of toughness at low temperatures, high strength at elevated temperatures, and weldability, offer the pressure vessel designer the *only* material of this high-strength level possessing *all* the qualities so important in the pressure vessel field. For more information, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS and "T-1" are registered trademarks

USS

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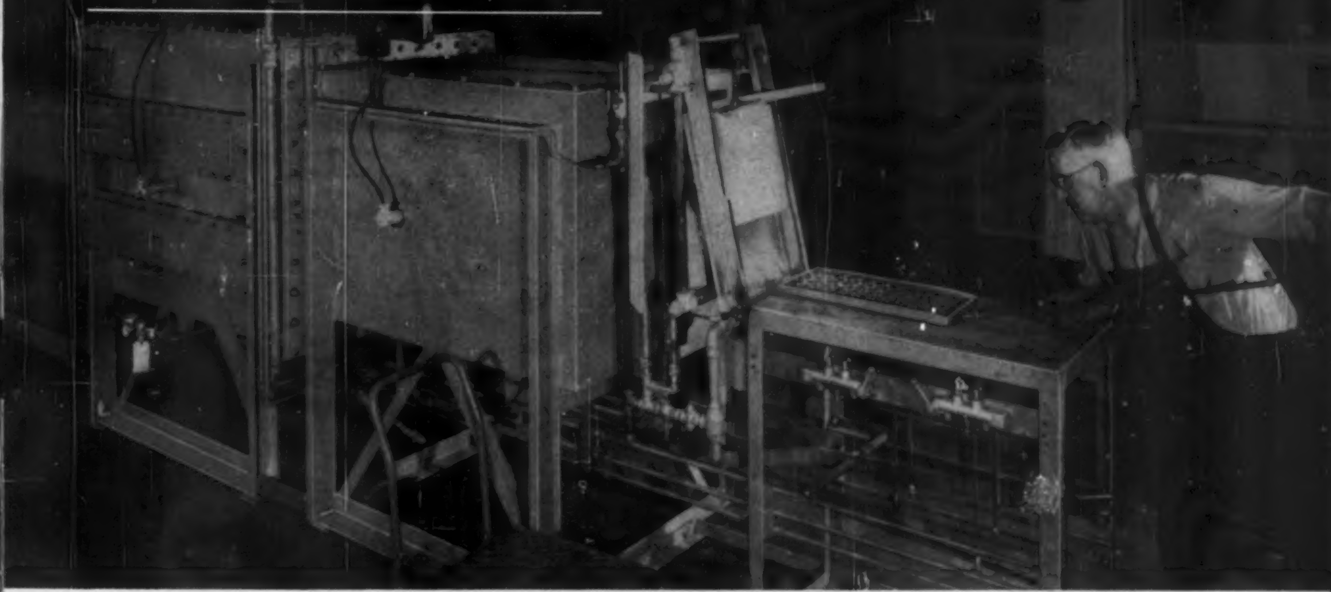
Colombia-Geneva Steel — San Francisco
National Tube Division — Pittsburgh
Tennessee Coal & Iron — Fairfield, Alabama
United States Steel Supply — Steel Service Centers
United States Steel Export Company

United States Steel

SINTERING PRECISION PARTS:



1. Green compacts are closely grouped on perforated steel trays for maximum productivity.

2. Loaded tray is pushed through gas flame curtain of open charging door into pre-heat chamber.

3. Trayload of sintered parts is drawn from cooling chamber through gas flame curtain of discharge door.

TEMPERATURES, ATMOSPHERES TIGHTLY HELD

Serving a large Eastern metal fabricator, this Harper Box Furnace sinters a variety of precision parts compacted from iron, iron graphite, 4600 series steel and brass powders. As the compacts move through the furnace's pre-heat, high temperature and cooling chambers, both temperature and atmosphere are controlled to insure precision work in numerous ways:

In the pre-heat (or burn-off) chamber, nickel-chromium elements provide temperatures up to 1500° F. An Inconel muffle retains protective atmosphere and prevents volatiles from collecting on the heating elements to cause short circuiting, muffling, grounding or chemical corrosion. Volatiles burned off at the top outlet are discharged through a vent pipe, while carbon and zinc oxide ash are readily brushed from the muffle.

After being pushed into the high temperature chamber, the parts can be processed at temperatures up to 2400° F. With the chamber's pneumatically-operated refractory doors acting as radiation screens, silicon carbide heating elements are arranged above and below the work to maintain the temperature desired within ±5° F throughout 32" of the 36" chamber length. Made of silicon carbide, the hearth plate retains its flatness under high temperatures.

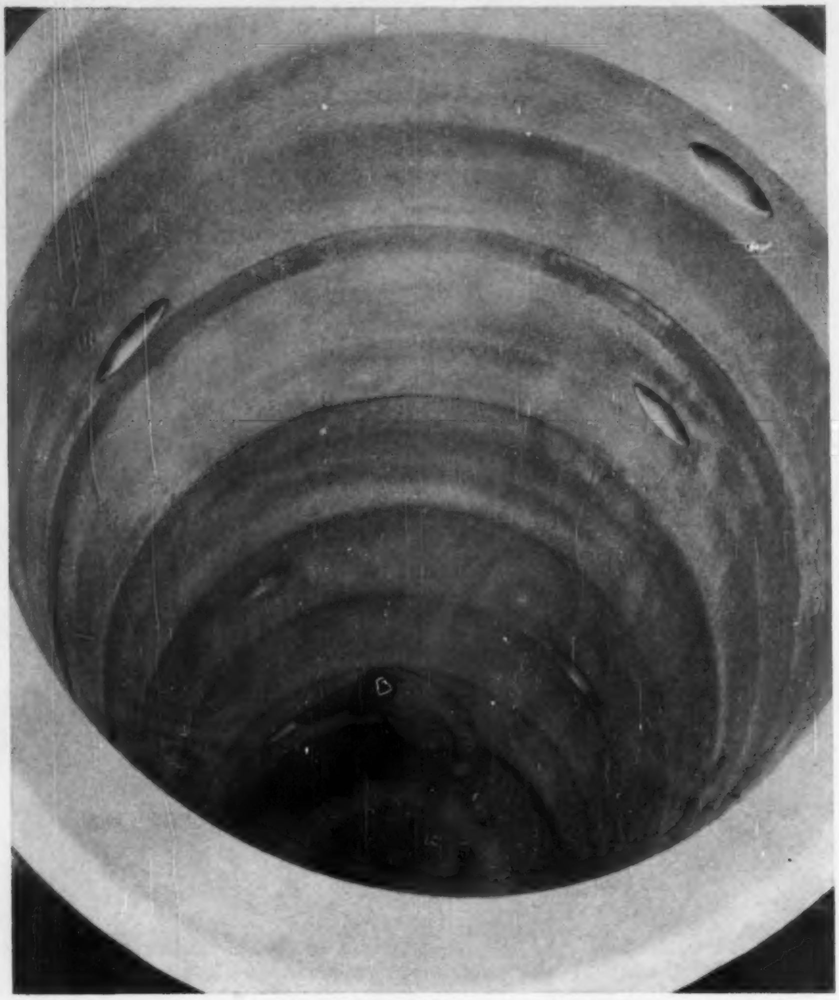
From the high temperature chamber, the parts enter the water-jacketed cooling chamber. Automatic control of water flow assists in regulating work temperature and prevents condensation within the liner during idle periods. From start to finish in this sintering operation, *Harper furnace features insure success.*

When it comes to a sintering or brazing furnace of any type — box, pusher, mesh belt, roller hearth, bell, elevator or pit — you'll find it pays to put it up to Harper — for Harper has the experience to both recommend and build the furnace that's best suited to your needs (with either gas or electricity or both as the source of heat). For more information, write: Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

HARPER ELECTRIC AND GAS FURNACES

FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH

How to reduce furnace heat loss



Vertical pit-type carburizing furnace (9' x 24') lined with a refractory insulating castable made with LUMNITE cement. Furnace temperature 1800°F. Badall Engineering & Manufacturing Co., Hammond, Ind. Castable used: "Kast-O-Lite," product of A. P. Green Fire Brick Co., Mexico, Mo.

Refractory insulating concrete, made with LUMNITE calcium-aluminate cement, is being specified for linings in many types of industrial furnaces. It helps trim fuel costs by reducing heat loss and increasing heat storage. This helps shorten heating-cooling cycles and provides closer temperature control. In addition, the smooth, jointless concrete surface reduces air infiltration.

Construction with refractory concrete is fast, easy, economical. Linings can be cast in place, troweled or "gunited." Service strength is reached in 24 hours.

For convenience, manufacturers of refractories offer castables bonded with LUMNITE cement — packaged mixtures ready for use with just the addition of water. For more information, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

 L-193

USS **Universal Atlas Cement Division of United States Steel**

OFFICES: Albany • Birmingham • Boston • Chicago • Dayton • Kansas City • Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh • St. Louis • Waco

Metal Progress

Volume 76

July 1959 through December 1959

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Metals Park, Novelty, Ohio

Subject Index

The subject headings used in this index are chosen in accordance with the ASM-SLA Metallurgical Literature Classification, International (Revised) Edition, published by the American Society for Metals, 1958.

***(aa)* Atomic Age; *(br)* Book Review; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Digest; *(ds)* Data Sheet; *(sr)* Short Runs**

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Author Index

Behind the By-lines

The article on "What's New in Tungsten Research" (p. 71) is based on a special conference held at Duke University and covered for *Metal Progress* by W. W. Austin. Bill Austin became interested in teaching as a career while a graduate student at Vanderbilt University. Although he turned to industry, he still followed this interest as a sideline, teaching on-the-job training courses in aircraft materials at Convair during World War II and serving as a member of the extension faculty of the University of Alabama while on the staff of the Southern Research Institute. In 1952, however, he finally yielded to his yen for teaching and joined the North Carolina State College faculty where in 1954 he initiated an undergraduate and graduate program in metallurgical engineering. A professor of metallurgical engineering, Dr. Austin also heads the department of mineral industries.

Dr. Austin's family consists of a wife and four youngsters ranging in age from 4 to 16. It's little wonder then that the majority of his outside interests center around his home – on work shop, garden and home projects. When not there, he can often be found at A.S.M. meetings (he is past chairman of the Birmingham Chapter and current chairman, 1959-60, of the Carolinas Chapter).

After reading the article on archeological metallurgy in the Light Metallurgy section on p. 94, it is not difficult to see which way lies the interest of David J. Mack (below), professor of metallurgical engineering at the University of Wisconsin. Although, technically, his tastes are varied, ranging from solid-state reactions (principally eutectoid reaction) to the plasticity of intermetallic compounds, his basic love is metallography. A native of Madison, Wis., he spent 14 years working in industry and teaching at Purdue and Tennessee before he returned to Madison and the University of Wisconsin. According to Professor Mack, over the years he has acquired a wife, two children, various pets, a house, two cars and several interests –

in collecting old houses (photographically, that is), sour mash bourbon and indoor bird watching. He has another seasonal "hobby": sleeping in the sunshine – sometimes called "gardening".

The article on p. 119 discussing B 120 VCA, an age hardening titanium alloy, is the cumulative effort of three metallurgists at Crucible Steel Co. of America – Vincent C. Petersen, Milton Vordahl and Howard B. Bomberger (shown in that order in the photo

above). Mr. Bomberger is supervisor of the fundamental research section of Crucible's Midland Research Laboratory, with special interests along the lines of corrosion and titanium metallurgy. His background includes work for the Wright Aeronautical Corp. and Buckeye Steel Casting Co. Since 1947 Mr. Vordahl has worked on titanium research first for Rem-Cru Titanium, Inc., and then for Crucible. At the present time he is chief research metallurgist at Midland. The most recent addition of the three is Mr. Petersen who joined Crucible in 1955 after seven years working on physical metallurgy of titanium for the U. S. Bureau of Mines and is now a research metallurgist in charge of the metallography group.

Our three authors share one common outside interest – all are members of A.S.M. Besides his technical interests, Mr. Bomberger is president of the local P.T.A. and enjoys reading, gardening, traveling and photography. Another gardening enthusiast is Milton Vordahl (though he claims his interest is limited to "edibles"); golf, minor construction and travel take up the remainder of his spare hours. When Vincent Petersen isn't hiking with his three children, he may be found at his other favorite activities: playing bridge and studying the very inexact science of finance.

R. J. Morris was introduced to metallurgy through a summer job on the hot strip mill at Granite City Steel Co. After graduating from the Missouri School of Mines, he worked for General Motors Corp. and P. R. Mallory Co. (both in Indianapolis) before returning to his studies at the graduate school of the University of Cincinnati. In 1955 he joined the flight propulsion laboratory department of General Electric and during the past four years has worked on investment cast alloys for buckets and high-strength, high-tempera-

Behind the Bylines . . .

ture wrought nickel-base alloys such as René 41 (see his authoritative article on p. 67.) He recently moved into advanced rocket nozzle materials development as manager of the rocket engine section.

L. J. Hull is well qualified to write an article about A-286 (p. 76), a fast growing superalloy, since he is supervisor of the metallurgy group at Ryan Aeronautical Co. To familiarize engineers, quality control men and others with the 60 to 70 different metals and alloys in production at Ryan, Mr. Hull is conducting in-plant training courses on aircraft metals (the photo shows him in action). Apart from this engrossing sideline, Mr. Hull takes advantage of the Southern California sun for hiking and photography.

George W. Wardwell, chief metallurgist for Rolock, Inc., is shown in the picture at the right examining one of the trays he discusses in his article on designing trays for roller hearth furnaces on p. 81. Although Mr. Wardwell does his share in community projects, his main interests lie at home, not unnaturally since it is located on a beautiful lake with swimming, boating and skating at his doorstep. He and his wife have toured the United States by auto and are now planning an extensive trip through Europe.

The three metallurgists pictured on the next page examining a test vessel are V. W. Cooke, C. E. Spaeth and J. E. Coyne, authors, together with M. E. Shank, of the two-part article on "Solid-Fuel Rocket Chambers for Operation at 240,000 Psi. and Above", concluded on p. 84 of this issue. Messrs. Cooke, Spaeth and Coyne are all with Pratt & Whitney Aircraft (where this photo was taken) while Dr. Shank is an associate professor of mechanical engineering at Massachusetts Institute of Technology and a consultant to Pratt & Whitney. Mr. Cooke is general supervisor of metallurgy in the materials development laboratory. Mr. Coyne is a project metallurgist in the laboratory and Mr. Spaeth is a senior design engineer. The other member of this team, M. E. Shank, has been on the faculty

of M.I.T. since he completed his doctorate degree there in 1949 and is in charge of undergraduate courses on the mechanical behavior of metals. His particular interest lies in the area of fracture, especially the phenomenon of brittle fracture in steels.

When not occupied with metallurgical matters, Dr. Shank likes to work on and around his home, overlooking Fairhaven Bay on the Sudbury River, a favorite fishing haunt of Thoreau.

A total of more than 30 years experience in metallography and metallurgy went into the article on sodium bisulphite as an etchant for steel by J. R. Vilella (right) and W. F. Kindle (below) on p. 99. Mr. Vilella has spent the past 30 years and more in metallurgy with Union Carbide and U.S. Steel. Author of many papers on metallography, he also delivered the 1951 Howe Memorial Lecture for the A.S.M. Mr. Kindle was Mr. Vilella's assistant for four years in metallography work and spent several weeks at the Bausch and Lomb plant in Rochester studying the optical and mechanical construction of various types of microscopes.

When it comes to nontechnical interests, Mr. Vilella prefers photography and bird watching, while Mr. Kindle goes in for bowling and "gardening".

The second article in the New Techniques for Etching section on p. 101 is by W. N. Posey who has been in charge of metallography and mechanical testing at the pile materials division of Du Pont's Savannah River Laboratory for the past three years. This article on etching uranium for bright-field examination evolved from a study of bond zone of fuel-clad elements.

Although he has three young sons to keep him more than busy, he still finds time for golf and work in the Boy Scouts and Civil Defense.

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METALGRAMS

...news about metals and metal chemicals

UNION CARBIDE METALS

Electromet brand ferroalloys, pure metals and metal chemicals

NOVEMBER - DECEMBER, 1959

With 100 million pounds of polypropylene predicted for 1960 production, Union Carbide Metals' titanium trichloride will reach commercial status as a polymerization catalyst. But the Company's researchers are also looking to other fields for new uses of this high-purity compound. Areas of interest include the chemical and pharmaceutical industries where titanium trichloride has potential as a strong reducing agent ($E° = -0.15$ volts) for nitro compounds, biologicals, and other organics. Request Bulletin TT1-P4 for more details.

* * *

Columbium metal has finally yielded to casting techniques due to the efforts of engineers at Materials Manufacturing Department of the Westinghouse Electric Corporation, Blairsville, Pa. What is believed to be the first columbium casting made is an experimental tube blank measuring 4 in. O.D. by 1¼ in. I.D. and 10 in. long. Using "ELECTROMET" columbium roundels, the metal was melted in a vacuum-arc skull furnace and cast in a graphite mold. Bulletin CB2-P4 gives information on columbium metal and sheet.

* * *

Chloride derivatives of lower valent transition metals are Union Carbide Metals' latest contribution to chloride chemistry. The Company's research team has produced, in experimental quantities, subchlorides of Cb, Cr, Ti, V, W, and Zr. Some of these have not been made before. "Electromet" subchlorides are potentially applicable as catalysts, metal-plating compounds, reductants in organic syntheses, and as intermediates for new organometallics. Bulletin MC1-P4 available.

* * *

The largest order for wrought vanadium ever placed was recently awarded to Union Carbide Metals Company. The contract calls for approximately 300 pounds of vanadium mill products which will be used in an undisclosed military application. The Company's continuing efforts to increase the purity of vanadium metal have led to mill products with improved workability. Get Bulletin VM1-P4 on vanadium metal.

* * *

In resistance to oxidation and corrosion, chromium carbide excels most other metal carbides. Its high hardness makes it useful when bonded with nickel or other metals. For use in the tool industry, Union Carbide Metals' chromium carbide is being pressed or sintered into dies and gage blocks whose thermal expansion characteristics are close to those of steel. This refractory compound has also been applied to surfaces by various metallizing methods. Send for Bulletin CC1-P4.

* * *

Silicon nitride which is 100% beta phase has recently been made possible by improved manufacturing techniques at Union Carbide Metals. Fabricated shapes of this new form of silicon nitride have extraordinary thermal shock resistance compared to previous alpha-beta mixtures. Foreseen applications include a refractory exposed to the combustion products of rocket fuels. See Bulletin SN1-P4.

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